Rees's Manufacturing Industry
(1819-20)

Volume One

A selection from
The Cyclopaedia; or Universal Dictionary of Arts, Sciences and Literature
by
ABRAHAM REES

Edited by Neil Cossons

DAVID & CHARLES REPRINTS

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Introduction

Abraham Rees's monumental *Cyclopaedia, or Universal Dictionary of Arts and Sciences . . .* which appeared in parts between 1802 and 1819 was one of the first works of its kind to be published in English which gave more than passing reference to contemporary industry and technology. Indeed, 'Rees' is one of the most valuable and comprehensive sources of information on manufacturing processes and techniques in the early years of the nineteenth century and as such is highly regarded by students and scholars of economic, industrial and technological history as a basic and fundamental starting point for further and more specific researches. It forms a major work of reference on many other subjects too, with great attention being paid to English biography, a massive and detailed coverage of botany at an important period in the advancement of botanical research, and articles on agricultural husbandry, astronomy, horology and naval architecture, for example, all regarded today as valuable, and in some cases unique, sources of summary information.

This new edition is an attempt within the limits of modern reprint technique to provide as complete a collection as possible of the Rees entries relating to industry and technology. By maintaining an alphabetical format it has been possible to provide a comprehensive but at the same time concentrated selection of relevant material assembled from the thirty-nine volume bulk of the original into an easily referred to form. There have been some minor losses, however, resulting largely from the technical problems of reprinting a work made up of individual articles of widely varying size. Small entries of less than half a column have, unless of exceptional significance, been omitted as have numerous one or two line dictionary definitions hardly appropriate to the scale of the major articles. Thus this new edition consists of those articles for which Rees is well known in the field of industrial and technological history, accompanied by the corresponding illustrations.

Abraham Rees was born in Llanbrynmair, Montgomeryshire in 1743, the son of Lewis Rees an independent minister and pillar of the nonconformist cause in South Wales. Abraham was educated for the ministry in London, entered in 1759, and subsequently held a number of positions as tutor in mathematics and natural philosophy, tutor in Hebrew and mathematics, and assistant preacher, all of them in London. In 1783 he went to the pastorate of the Old Jewry congregation, a position he retained until his death in 1825. In 1775 he received the degree of doctor of divinity from Edinburgh University.

Rees's work as a cyclopaedist began in the 1770s when he re-edited the cyclopaedia of Ephraim Chambers originally published in two volumes in 1728. The success of the new Rees edition, published in 1778, and reprinted in 1788–91, gained him recognition in 1786 when on 1 June of that year he was elected a Fellow of the Royal Society. The certificate of candidature described him thus: 'Abraham Rees, of the Old Jewry, D.D., Editor of the new and improved Edition of Chamber's Cyclopaedia now completed and a Gentleman well versed in the different Branches of Mathematics and Natural Philosophy, . . .' Later Rees was elected a fellow of the Linnean Society and the American Society. His success with Chambers led Rees to project a similar but more comprehensive work on a much larger scale and the first part of *The New Cyclopaedia, or Universal*

Dictionary of Arts and Sciences . . . Biography, Geography, and History, etc, was issued on 2 January 1802. It was completed, in forty-five volumes, including six volumes of plates, in August 1820. Congratulated by his friend John Evans on the completion of his gigantic task, Rees wrote in reply: 'I thank you, but I feel more grateful that I have been spared to publish my four volumes of sermons.' These he completed in 1821.

Rees's Cyclopaedia was issued in parts, two of which formed a volume. These parts appeared at irregular intervals and on completion of the work a set of title pages was issued bearing the date of the last, namely 1819 for thirty-nine volumes of text, and 1820 for six volumes of plates.

Various attempts have been made to define the dates of issue of the sections of Rees, the most complete being published by Benjamin Daydon Jackson in 1895—*An Attempt to Ascertain the Actual Dates of Publication of the various parts of Rees's Cyclopaedia.* This chronology is based on a variety of evidence but nevertheless gaps exist. Jackson's main sources were the *Monthly Literary Advertiser* published on the 9th or 10th of each month and a rare set of the *Cyclopaedia* in their original unbound state. Although Longmans, the original publishers, had no information on the dates of publication, and no dates appeared on the individual parts, a list of new books by the publisher was printed on the inside cover of each part, generally dated and in some cases by the day of the month.

These two authorities added together still left many gaps which in part have been filled by evidence from the plates issued with each part. Unfortunately the plate dates vary widely, even within a single issue, and in some cases no date whatever is provided—only, 'Published as the Act directs, by Longman', etc. Within one pair of covers dates as far apart as 1805 and 1813 occurred.

The custom of dating plates arose in order to preserve the copyright in the engraving. In 1735 an Act, (8 George III, c 13) specified this and stated that the designer '. . . shall have the sole right and liberty of printing and reprinting the same for a term of fourteen years, to commence from the day of the first publishing thereof, which shall be truly engraved with the name of the proprietor on each plate, and printed on every such print or prints'. In 1767 the term of years was extended to twenty-eight, the occasion being to protect the engravings after Hogarth's pictures. A decision of Chief Justice Best,made in 1816, shows that the law had not been relaxed although the practice, as shown in the *Cyclopaedia*, had. The Copyright Act of 1842 superseded these provisions, thenceforth every map or engraving in a copyrighted book shared in the overall protection.

The following list propounded by B. D. Jackson is broken down under the volume and its part and the running number of each part as frequently quoted in the *Monthly Literary Advertiser.* Next follows the contents—the first and last article in each part, then the nearest date assigned to it, authenticated by the source of information. The initials *M.L.A.* indicate *Monthly Literary Advertiser*, and are probably the most accurate. Next the booklists on the inside covers provide a closing date for the issue of each part. Finally, a few dates have been ascribed from amongst the plates in each part, the latest date on a plate being given in each case. These latter are probably worth very little.

Vol.	Sect.	Part.	Contents.	Date.	Authority.
1	I.	1	A—Agoge	2 Jan., 1802	Book List.
	II.	2	Agogliastro—Amaranthoides ...	2 May, 1802	Last Plate.
2	I.	3	Amaranthus—Antimony	2 Sept., 1802	Do.
	II.	4	Antimony—Arteriotomy	2 May, 1803	Do.
3	I.	5	Artery—Babel-mandeb	— Aug., 1803	Do.
	II.	6	Babenhausen—Battersea	1 Feb., 1804	Do.
4	I.	7	Battery-point—Biörnstall	1 Aug., 1804	Do.
	II.	8	Biot—Bookbinding	1 Feb., 1805	Book List.
5	I.	9	Bookkeeping—Brunia	1 Sept., 1805	Last Plate.
	II.	10	Brunia—Calvart	?	
6	I.	11	Calvary—Cape of Good Hope ...	17 Feb., 1806	Book List.
	II.	12	Cape of Good Hope—Castra ...	23 May, 1806	Do.
7	I.	13	Castramentation—Chalk	30 Sept., 1806	Do.
	II.	14	Chalk—Chronology	1 Jan., 1807	Do.
8	I.	15	Chronometer—Clavaria	— Jan., 1807	*M.L.A.*
	II.	16	Clavaria—Colisseum	1 Aug., 1807	Book List.
9	I.	17	Collision—Congregation	— Dec., 1807	Do.
	II.	18	Congregation—Corne	1 March, 1808	Do.
10	I.	19	Cornea—Croisade	—May, 1808	*M.L.A.*
	II.	20	Croisade—Czyreassy	27 June, 1808	Book List.
11	I.	21	D—Deluge	24 Sept., 1808	Do.
	II.	22	Deluge—Dissimilitude	28 Nov., 1808	Do.
12	I.	23	Dissimulation—Dynamics... ...	— March, 1809	*M.L.A.*
	II.	24	Dynamics—Eloanx	— June, 1809	Do.
13	I.	25	Elocution—Equation	14 Aug., 1809	Book List.
	II.	26	Equation—Extremum	— Dec., 1809	*M.L.A.*
14	I.	27	Extrinsic—Fibro-cartilage ...	—Apl.(?), 1809	Book List.
	II.	28	Fibro-cartilage—Food	1 Feb., 1810	Last Plate.
15	I.	29	Food—Froberger	23 June, 1810	Book List.
	II.	30	Frobisher—Generation	8 Oct., 1810	Do.
16	I.	31	Generation—Gniewe	— Dec., 1810	*M.L.A.*
	II.	32	Groien—Gretna-Green	— Jan., 1811	Do.
17	I.	33	Gretry—Hatfield-Regis	?	
	II.	34	Hatfield-Regis—Hibe	12 April, 1811	Book List.
18	I.	35	Hibiscus—Huysum	1 May, 1811	Last Plate.
	II.	36	Huzanka—Increment	1 Aug., 1811	Book List.
19	I.	37	Increment—Josephus	1 Sept., 1811	Last Plate.
	II.	38	Josephus—Kilmes	— Dec., 1811	Book List.
20	I.	39	Kiln—Lauremberg	?	
	II.	40	Lauremberg—Lights	—March, 1812	Book List.
21	I.	41	Light-house—Longitude	?	
	II.	42	Longitude—Machinery	?	
22	I.	43	Machinery—Manganese	?	
	II.	44	Manganese—Macheson	— Oct., 1812	Book List.
23	I.	45	Matthew—Metals	— Dec., 1812	Do.
	II.	46	Metals—Monsoon	— April, 1813	*M.L.A.*
24	I.	47	Monster—Muscle	?	
	II.	48	Muscle—Newton	?	
25	I.	49	Newtonian—Oleinæ	?	
	II.	50	Oleinæ—Ozunicze	?	
26	I.	51	P—Passiflora	?	
	II.	52	Passiflora—Perturbation	— Dec., 1813	Book List.
27	I.	53	Pertussis—Picus	— March, 1814	Do.
	II.	54	Picus—Poetics	?	
28	I.	55	Poetry—Preaching	?	
	II.	56	Preaching—Punjoor	?	
29	I.	57	Punishment—Ram	?	
	II.	58	Ram—Repton	— Dec., 1814	Book List.
30	I.	59	Republic—Rock	?	
	II.	60	Rock—Rzemien	—— 1815	Last Plate.

Vol.	Sect.	Part.	Contents	Date.	Authority.
31	I.	61	S—Sarabanda	?	
	II.	62	Sarabanda—Scotium	— Sept., 1815	Book List.
32	I.	63	Scotland—Shammy	— March, 1816	*M.L.A.*
	II.	64	Shammy—Sindy	?	
33	I.	65	Sine—Sound	— May, 1816	Book List.
	II.	66	Sound—Starboard	— July, 1816	Do.
34	I.	67	Starch—Stuart	— Nov., 1816	*M.L.A.*
	II.	68	Stuart—Szydlow	20 Dec., 1816	Do.
35	I.	69	T—Testudo	— Feb., 1817	Book List.
	II.	70	Testudo—Toleration	?	
36	I.	71	Tolerium—Tumours	— Aug., 1817	Book List.
	II.	72	Tumours—Vermelho	24 Oct., 1817	*M.L.A.*
37	I.	73	Vermes—Union	23 Dec., 1817	Do.
	II.	74	Union—Wateeoo	?	
38	I.	75	Water—Whitby	28 May, 1818	*M.L.A.*
	II.	76	Whitby—Wren	31 July, 1818	Do.
39	I.	77	Wren—Zyto: Aam-Baldwin ...	— Jan., 1819	Do.
	II.	78	Baldwin—Zollikofer. Titles ...	— Nov. 1819	Do.
	III.	79	Titles, Preface, Plates	?	
	Part A		Plates to complete.	?	
	„ B		Do.	?	
	„ C		Do.	?	
	„ D		Do.	?	
	„ E		Do.	?	
	„ F		Do.	("last") Aug., 1820	*M.L.A.*

Preface

THE CYCLOPÆDIA, which has been the production of the incessant labour of almost twenty years, is now completed, very much to the relief of the Editor's mind, and, as he hopes, to the satisfaction of the Public. To the candid judgment of its numerous readers, the Editor submits the work, assuring them, that, on his part, no pains have been wanting to render it worthy of their approbation. If he had foreseen the time and attention which the compilation and conduct of it required, and the unavoidable anxiety which it has occasioned, he would probably never have undertaken it. But habits of application, and some degree of experience in a work of this nature, disposed him to embark in it, and enabled him to overcome the difficulties that presented themselves to his view in his further progress. He hopes that he may be allowed to say, that an early and long-continued attachment to scientific pursuits, and a desire of serving the cause of Literature and Science, had no inconsiderable influence in directing his views to this object, and encouraging his perseverance in the accomplishment of it. He ought also to acknowledge, that the candour with which his labours, on this as well as on a former similar occasion, were received by the Public, and the expressions of approbation with which they were honoured in the course of sixteen years, afforded a very powerful inducement to unremitting assiduity and exertion. The Proprietors also, who had undertaken this work without any patronage besides that of the Public, and who were advancing large sums towards rendering it worthy of that patronage, were liberal in their co-operation, and in enabling the Editor to procure every kind of assistance, which he might find to be necessary and useful. They employed artists of the first reputation in their respective departments, whose performances have given a peculiar character to this work. The Proprietors and Editor were likewise honoured by connection and acquaintance with persons, eminently distinguished in those branches of science to which they had devoted their talents; and these persons not only consented to be co-adjutors, but to give celebrity to the work by allowing their names to be annexed to it, whilst they were enhancing its importance and value by their contributions. Although the Editor cannot decline availing himself of the reputation which the Cyclopædia must acquire from the established and well-known character of his associates,

and with this view presenting their names to the Public, he does not wish to rob them of any portion of fame that belongs to them, in order to enrich himself. Notwithstanding all the assistance which he has received, and which he thus gratefully and respectfully acknowledges, his own responsibility furnishes a large demand on the candour of the Public; nor will those who duly consider, that he has devoted almost twenty years of his life, measured not by fragments of time, but by whole days of twelve or fourteen hours, to the completion of his undertaking, and in so doing impaired his health and constitution, be indisposed to exercise that liberality in their estimate of his labours which he solicits. He is not unapprised of defects and imperfections; and if he were to begin the Cyclopædia *de novo*, he could improve it. Science is progressive; and since the commencement of this work, its advances in several departments have not been inconsiderable. The Editor has endeavoured to watch its steps, and to incorporate in his pages every discovery and improvement that has attended its progress. He now presents his work, in its finished state, at the bar of the Public, anxiously but not timidly waiting a favourable decision. He begs leave, however, to suggest, that he does not consider himself as responsible for the opinions advanced by his co-adjutors in the articles which they have furnished, any more than for those which occur in extracts from printed works. Some of these seem to him to be erroneous; and they are actually controverted and contradicted in other parts of the Cyclopædia, where the mention of them occurs. As he could not prescribe limits to the articles supplied by his co-adjutors, he could not presume to prohibit a statement of their own sentiments on the subjects of the articles which they contributed. In every case the reader will form his own judgment.

The names of most of his co-adjutors have been already published on the covers of several parts of the work; but after he has again recited them, every reader will be able to assign to each, so well known in the circle of science, the articles of any extent and of principal importance, which he has furnished. Under each head, the arts and sciences being arranged in alphabetical order, will be mentioned the names of those to whom the Editor is indebted for contributions; though in some cases the number is small and the articles are short, whilst in others they are more numerous and more extended. Many of these articles have been considerably enlarged in consequence of the Editor's own researches. His own additions are so incorporated with the communications of his friends, that it would not be easy to distinguish them without a minuteness of detail, which, as he conceives, would be tedious and uninteresting. *Agriculture*, Dr. Dickson. — *Algebra* and *Analysis*, Barlow, Bonnycastle, and Pond. —*Anatomy* and *Physiology*,

Abernethy and Lawrence. — *Comparative Anatomy*, Macartney, Lawrence, and Clarke. — *Annuities*, W. Morgan. — *Antiquities*, H. Ellis and Strutt. — *Architecture*, Porden, E. Aikin, P. Nicholson, Dr. Milner, and Webster. — *Astronomy*, Bonnycastle and Pond. — *Astronomical Instruments*, Rev. Dr. Pearson. — *Biography*, Sir J. E. Smith, Dr. Burney, Dr. Malkin, and Dr. T. Rees. — *Botany*, Sir J. E. Smith, Dr. Woodville, Rev. Mr. Wood. — *Canals*, Farey, senior. — *Chemistry*, Aikin, Sylvester, Dalton, Brande, Dr. Marcet, Sir Humphrey Davy, Dr. C. Taylor, and Dr. Davy. — *Conic Sections* and *Curvilinear Geometry*, Ivory. — *Drawing*, Howard. — *Dynamics*, Cavallo. — *Education*, Dr. Carpenter. — *Electricity*, Cavallo and Cuthbertson. — *Engraving*, Landseer. — *Entomology*, *Conchology*, and several other articles of *Natural History*, Donovan. — *Exchange*, *Standard*, *Coinage*, and *Weight*, Dr. Kelly. — *Blast* and *Blowing Furnaces*, Mushett. — *Geology*, Kœnig, Bakewell. — *Geography*, Tooke, Hinckes. — *Geometry*, Barlow, Ivory. — *Grammar*, Dr. Jones. — *Heraldry*, Sir G. Naylor. — *History*, *English*, S. Turner and Owen Pugh. — *Horology*, Rev. Dr. Pearson. — *Language*, Dr. Carpenter, Dr. Jones. — *Magnetism*, Cavallo. — *Manufactures*, Duncan, J. Thomson, Parkes, and Farey, junior. — *Mechanics* and *Machinery*, Cavallo, Farey, junior. — *Medicine*, Dr. Bateman and Dr. Henderson. — *Mental Derangement*, Dr. Haslam. — *Meteorology*, L. Howard, Dalton, and Dickson. — *Midwifery*, Dr. Bland. — *Mineralogy*, Kœnig, Bakewell. — *Mining*, Taylor. — *Naval Architecture*, Glover. — *Navigation*, Mackay. — *Music*, Dr. Burney and Farey, senior. — *India Mythology*, Major Moor. — *Mental* and *Moral Philosophy*, Dr. Carpenter. — *Painting*, Russell, Opie, Ottley, and Phillips. — *Prosody*, H. Parker. — *Sculpture*, Flaxman, P. Hoare, and Bacon. — *Surgery*, Blair, who also furnished the article *Cipher*, and S. Cooper. — *Topography*, Britton. — *Versification*, H. Parker; — and a variety of *Miscellaneous* articles by Joyce, Ellis, Fletcher, Howard, Clarkson, and several other gentlemen, who were occasional contributors, and whose names it is needless to mention. To Mr. S. Bevan and some other literary and scientific friends, the Editor is indebted for the assistance which they have afforded him in suggesting articles that had been omitted, and that have been supplied in the *Addenda*. Dr. Thomas Rees has, towards the close of the work, paid particular attention to the arrangement of the Plates. He has also drawn up a digested catalogue of them, together with an alphabetical index of the subjects which they comprise; and added such explanations, and corrections of references, as appeared to be necessary or desirable, after a minute and careful collation, made in conjunction with the Editor, of every Plate, with the printed letter-press to which it pertained. The Editor and Proprietors of this work are also indebted to

Mr. Donovan, for the General Systematic Arrangement of the Plates of Natural History.

The general plan upon which this work has been conducted, and which was stated in the Advertisement that announced the publication of it, seemed to the Editor, after some experience in this department of literary labour, and after consulting several competent judges, the most suitable to the nature and design of a Scientific Dictionary. Whatever may be the advantage resulting from separate dictionaries appropriate to each particular science, which is the plan of the French Encyclopedie, or from distinct treatises introduced in a dictionary of one alphabet, according to some modern compilations of this kind, the inconvenience and perplexity that attend the multiplication of alphabets, whether they occur in different serieses of volumes, or in the form of an index at the close of each treatise, will furnish an objection against this mode of arrangement, which it will not be easy to obviate. In a work of such magnitude as the French Dictionary, consisting already of between 100 and 200 volumes, and of undetermined extent, the best treatises that have been written, or that may be written, on each subject, may be introduced, and the work itself may be a complete library, and supersede the necessity of recurring to any other. But in a publication of limited compass, such as booksellers may undertake, and the general class of readers purchase, it is hardly possible to combine separate articles, sufficiently instructive, with treatises equally comprehensive and complete. To those who usually consult dictionaries for information, this plan, we are persuaded, is by no means the most eligible. If they wish to extend their knowledge beyond the limits to which a dictionary must necessarily restrict it, they will recur to appropriate treatises for the purpose; and the dictionary should furnish them with the necessary references. A dictionary is intended for communicating knowledge in an easy and expeditious manner; and it is desirable that the several articles should be so full and comprehensive, as to afford sufficient instruction on the subjects to which they relate, without the necessity of recurring to another dictionary, or to an index, for further information. It may be said, indeed, that the sciences are thus mutilated and mangled; and that it is impossible to preserve their unity without discussing each in a separate treatise. We readily allow, that this is an inconvenience, inseparable from the form of a dictionary; but at the same time we think that this may be remedied in a considerable degree by that kind of ramification of the principal subject, which, with suitable references, will lead the reader to subordinate articles, that form, by their mutual connection and dependence, an aggregate or whole, superseding in all common cases the necessity of a distinct treatise. These

references, when judiciously distributed and arranged, will serve, like the index of a book, but much more effectually, to conduct the reader from one subject to another: they will enable him to perceive their relation to each other; and they will direct him how to collect and combine the dispersed parts of any science into one entire and regular system. Each article will afford him, as it were, a distinct lecture; and he may pursue the same course of study by the means now suggested, or vary it as he thinks proper. Upon the whole, the advantage of separate treatises under each head of science, such as the limits of a dictionary will allow, seems to be more imaginary than real; more especially as the want of them may be supplied in the manner that has been mentioned.

In conformity to our proposed plan, it has been our endeavour to give, under each distinct head of science, an historical account of its rise, progress, and present state, concisely and yet as comprehensively as our limits and our sources of information would allow; to refer to those articles in which the discussion of them occurs, and to point out such publications as afford further information. References of this kind are introduced under each separate article, wherever they are thought to be necessary and useful; and thus the reader is able to form his judgment concerning the authorities upon which the compilers of the several articles depend; and if he shall have opportunity or inclination, he may recur to them for himself.

Whilst the Editor and his co-adjutors in this work have availed themselves of the assistance which other similar dictionaries have afforded them, they have not contented themselves with mere transcripts; they have resorted as much as possible to original writers, which they have been enabled to do by the facility of their access to large libraries; and by the citations which they subjoin to the several articles, the Public will judge of the extent of their research, and of the industry and labour which they have bestowed on this compilation. In their account of the arts and manufactures, they have consulted the artisans and manufacturers themselves, and derived from them every kind of information that was likely to conduce to the credit and utility of the work: and this they have not been able to do without incurring a very considerable expence.

Some apology may, perhaps, be thought necessary for the extension of this work beyond the limits first proposed. When it was determined to introduce biography, as well as geography, topography, and history, upon a larger scale than the Proprietors and Editor had at first intended, principally

in compliance with the wishes of intelligent and esteemed subscribers, the enlargement of it became indispensable. To his co-adjutors, whose assistance was highly important, the Editor could not presume to prescribe limits, which would have depreciated the value of the articles which they contributed, and within which, for their own reputation, they would not have consented to be confined, and of course the work would have been deprived of the benefit of their contributions. This circumstance could not fail to occasion an enlargement of the Cyclopædia; but it was proportionably enhanced in value; and the Editor is satisfied, that the purchasers will not ultimately regret the augmentation of expence. The plates likewise have been multiplied far beyond the original intention of the Proprietors, because new and unthought-of subjects were introduced in the progress of the work; but as these plates constitute a character of excellence peculiar to this Cyclopædia, it is thought that the circumstance of their being additional embellishments of the work, besides that of their being indispensable as explanatory of the articles to which they refer, will be a sufficient apology for the increase of their number; more especially when it is considered, that the augmented number of plates, as well as the enlargement of the work, have occasioned a diminution of profit to the Proprietors. It would have been more their interest, as well as more gratifying to the Editor, to have compiled a Cyclopædia in fewer volumes, and to have contented themselves with a smaller number of plates; as in all probability the sale would have been greater, and the sum of money expended upon it would of course have been much less. The Editor must do the booksellers concerned in this Cyclopædia the justice to say, that they have consented to forego part of the possible profit that might have accrued from it for the sake of its reputation and utility.

CYCLOPÆDIA:

OR, A NEW

UNIVERSAL DICTIONARY

OF

ARTS and SCIENCES.

Acetic Acid

ACETIC ACID, in *Chemiſtry*, *Radical vinegar*, *Acide Acétique*, *Vinaigre radical*, *Vinaigre de Vénus*. If any quantity of cryſtallized acetite of copper (diſtilled verdigriſe) be diſtilled in a glaſs retort, with a regulated heat, till at length the bottom of the veſſel is nearly red hot, the equilibrium of the affinity between the component parts of the ſalt will be deſtroyed, and ſeveral new ſubſtances in conſequence produced. The proportion of theſe on 1000 parts of the ſalt, according to an accurate analyſis of Cit. Adet, will be 486 acetic acid, 312 brown oxyd of copper mixed with charcoal, 118 hydrogen and carbonic acid gas, and about 84 of the acetite of copper, will remain undecompoſed. In order to be fully aware of what takes place in theſe changes, it is neceſſary to obſerve, that the cryſtallized acetite of copper contains hydrogen and oxygen forming the water of cryſtallization, hydrogen, carbon, and oxygen forming acetous acid, and copper, with about 25 per cent. of oxygen. By the proceſs of diſtillation, the acetous acid appears to be decompoſed by the ſeparation of part of its hydrocarbonous baſe, and at the ſame time the oxyd of copper is brought to a lower ſtate of oxydation: part of the carbon becomes acidified at the expence of the copper, and, uniting with the hydrogen, forms hydrocarbonous gas; the remainder of the carbon is found in the retort, mixed with the oxyd of copper, and poſſeſſes the properties of a pyrophorus. Thus it ſeems that acetic acid differs from acetous, in a larger proportion of oxygen to the baſe, which is effected not by an addition of oxygen, but by a diminution of the baſe. Acetic acid may alſo be procured by diſtilling together acetite of lead, of ſoda, potaſh, or lime, with ſulphuric acid; the product is however, in this caſe, contaminated by ſulphureous acid gas; but this may be in part prevented, by

adding to the materials fome black oxyd of manganefe. M. Badollier propofes to obtain acetic acid, by diftilling equal parts of fulphat of copper, and acetite of lead: the acid thus produced cofts only a fourth of that which is formed from acetite of copper. In its general properties, acetic acid is very fimilar to acetous acid, yet differing from it in the following particulars.

The active acid qualities of this fluid bring it to a near refemblance with fome of the mineral acids; it is corrofive, and intenfely acid to the tafte, exhales a pungent almoft fuffocating odour, and has nothing of the fpirituous flavour of diftilled vinegar: its fpecific gravity is 1.0626. With earthy and alkaline bafes it unites readily, forming the genus of neutral and earthy acetats, the properties of which have been but very little examined. It diffolves copper, and certain other metals which are not foluble in acetous acid, and it is capable of partly decompofing and uniting with alcohol, forming acetic Ether.

This acid is of fome ufe in the laboratory, and is employed occafionally in medicine, as a ftimulant application to the noftrils in fainting fits; for this purpofe fome acetite of potafh is put into a fmelling-bottle, and a little fulphuric acid is poured upon it. Annales de Chimie. xxvii. 299. xxviii. 113. Fourcroy, Syft. des Connaifs. Chim. viii. Gren's Chem. ii.

Acetite of Potash. *Kali acetatum*, Lond. Pharm. *Lixiva acetata* et *Tartar. regenerat.* Edin. Pharm. *Acétite de Potaffe. Terra foliata Tartari. Digeftive falt of Silvius.*

This falt occurs native in the fap, and certain other vegetable juices, and alfo in the urine of fome quadrupeds: it is prepared artificially by adding to pearlafh, or carbonat of potafh, diftilled vinegar, till the liquor contains a flight excefs of acid; if the falt is wanted in a folid ftate, evaporation in a glafs or filver veffel muft be had recourfe to; when a pellicle appears on the furface, the procefs fhould go on at a very gentle temperature, till all the moifture is exhaled; there will remain a white micaceous falt, which muft immediately, while warm, be put into a well-clofed vial. The falt may alfo be obtained cheap and pure, by adding fulphat of potafh to acetite of lime, evaporating to drynefs in a water-bath, and diffolving out the acetite of potafh by hot alcohol.

Acetite of potafh has a lively penetrating odour, and a fharp tafte; but leaving an alkaline impreffion on the palate: it cryftallizes in needles and plates, the form of which has not been afcertained.

This falt has a ftrong affinity for water, deliquiating readily in the air: it requires 1.021 parts of this fluid at 50° Fahren. for its folution, and, while diffolving, abforbs caloric: from its hot faturated folution in alcohol, cryftals may be obtained by cooling.

Of the alkalies and alkaline earths, barytes alone is capable of decompofing acetite of potafh, fetting at liberty the alkali, and forming with the acid acetite of barytes.

The fulphuric, nitric, muriatic, fluoric, phofphoric, oxalic, tartareous, arfénic, fuccinic and malic acids, are each capable of feparating the acetous acid from its alkaline bafe: all the eafily foluble fulphats, and feveral other neutral falts effect the fame by double affinity.

Acetite of potafh, fubjected to dry diftillation, yields hydrocarbonous gas, an ammoniacal liquor mixed with empyreumatic oil, fublimed cryftals of carbonat, or acetite of ammonia, and there remains in the retort, charcoal, with potafh, partly cauftic, and partly carbonated. The appearance of ammonia in this procefs, is a circumftance well worthy of accurate inveftigation: it was firft obferved by Beaumé, and afterwards by Morveau, and feems likely to throw much light on one of two very important queftions, viz. Is azot a compound? Is ammonia one of the elements of potafh? Ammonia confifts of azot and hydrogen, but acetite of potafh furnifhes only oxygen, hydrogen, carbon, and potafh; hence, it feems reafonable to fuppofe, either that thefe four fubftances contain the bafes of azot, or that ammonia is one of the component parts of potafh.

The above falt is applied to no ufe in the laboratory, or in the arts: it is an article of the Materia Medica, and poffeffes confiderable diuretic qualities.

Beaumé, Chim. Experim. Fourcroy, Connaif. Chim. Encycloped. Method. Art. Acète de Potaffe. Gren's Chemiftry.

Acetite of Soda. *Acétite de Soude. Terra foliata mineralis vel cryftallizata.*

To any quantity of carbonated foda add diftilled vinegar, leaving the liquor, however, ftill alkaline; evaporate gently to a pellicle, and by cooling, acetite of foda will be obtained in long ftriated prifmatic cryftals fimilar to thofe of fulphated foda, permanent in the air, foluble at a gentle temperature in their water of cryftallization, and of a pungent bitterifh tafte.

Acetite of foda is eafily foluble in water and alcohol, is decompofable with abftraction of the acid or alkaline bafe by potafh, and the fame fubftances as the preceding falt: when kept long in folution it is converted into carbonat of foda by decompofition of its acid; if fubjected to dry diftillation it yields hydrocarbonous gas, empyreumatic oil and acid, and there remains in the retort, charcoal and carbonated foda.

This falt is employed a little in France as a medicine—in this country is made no ufe of.

Beaumé, Ch. Exp.—Fourcroy, Syft. des Conn. Chim.—Encyclop. Method. art. Acétite de Soude—Gren's Chem.

Acetite of Ammonia. *Acetite d'Ammoniaque.—Ammonia Acetata* et *Spiritus Mindereri;* Lond. et Edin. Pharm.

This is prepared in the liquid form by adding carbonated ammonia to diftilled vinegar till faturation. On account of its great volatility, it is not very eafy to obtain it in the cryftalline form; the following method was fuccefsfully practifed by M. Delaffone for this purpofe: equal parts of chalk and fal-ammoniac were mixed well together, and put into a retort, upon which was poured half their weight of concentrated acetous acid; by a gentle heat a white vapour arofe, which concreted in beautiful cryftals in the receiver, and was acetite of ammonia. Another way of preparing this falt is by diftilling equal parts of acetated lead (fugar of lead), and muriated ammonia (fal-ammoniac.)

This fubftance is very deliquefcent—has a hot pungent flavour—is decompofed by alkalies, by moft acids, and by double affinity in various ways; it is deftroyed by fire, and fpontaneoufly when in folution.

It is only employed in medicine, and is confidered as a diaphoretic.

Beaumé, Ch. Exp.—Fourcroy, Syft. des Connaif. Chim.—Encyclop. Method. art. Acéte d'Ammona.—Gren, ut fupra.

Acetite of Lime. *Acétite de Chaux.—Salt of Chalk,—Salt of Coral.*

This falt is readily procured, by adding diftilled vinegar to chalk, marble, coral, oyfter-fhells, or any other fubftance that confifts chiefly of calcareous carbonat; the carbonic acid is difengaged with effervefcence, and by evaporating the folution to a pellicle, and allowing it to cool gradually, cryftals of acetite of lime are depofited.

Calcareous acetite cryftallizes in white flender filky filaments, permanent in the air; its tafte is bitter, acerb, rather cauftic; it is foluble with eafe in water, and in fmall

proportion

proportion by alcohol. Barytes, and the fixed alkalies decompose it, by union with its acid; the stronger acids do the same, by combining with its earthy base: most of the carbonats and sulphats decompose it by compound affinity: when in solution, it is destroyed spontaneously by decomposition of the acid, and deposits carbonat of lime: in dry distillation it yields hydrocarbonous gas, empyreumatic acid and oil, charcoal and calcareous carbonat.

It is still admitted into the foreign pharmacopœas as a sudorific and diuretic.

Beaumé, Ch. Exp.—Fourcroy, Syst. des Connaiss. Chim. Encyclop. Method. art. Acéte Calcaire.—Gren, ut supra.

Acetite of Barytes. *Acétite de Baryt.*

This salt is usually prepared by adding carbonat of barytes to distilled vinegar, in which case the acid is always in excess: when reduced by evaporation, to the consistence of a syrup, and allowed to cool gradually, it deposits a white opaque granular salt, and the sides of the vessel are covered with silky filaments of the same: a better way of procuring this substance, is by boiling for a few minutes the sulphuret of barytes in a slight excess of acetous acid, (vide Acetite of Strontian) filtering the solution, and setting it to evaporate spontaneously; transparent crystals may thus be obtained in long slender prisms. The salt formed by either of these methods is permanent in the air, and decomposable by most of the mineral acids, the carbonated alkalies, and the sulphuric salts. Its only use is as a reagent, for ascertaining the presence of sulphuric acid in those cases where the muriat or nitrat of barytes might affect the results of the analysis.

Encyclop. Method. art. Acéte Barotique.

Acetite of Strontian. *Acétite de Strontian.*

To any quantity of warm distilled vinegar, add gradually sulphuret of strontian, as long as any effervescence is perceived; then boil the liquor for a few minutes, and filter; add afterwards, drop by drop, a solution of acetite of lead, (sugar of lead) as long as any precipitate takes place, then suffer the liquor to stand for a few hours, and finally separate it from the dark sediment by filtration. This salt has not as yet been the subject of experiment; its properties are, in all probability, very similar to those of the Acet. Baryt. It is not made any use of.

Acetite of Magnesia. *Acétite de Magnesie.*

This salt is prepared by saturating distilled vinegar with carbonated magnesia, then boiling the liquor to separate the remains of carbonic acid and filtering it, if turbid, to get rid of the excess of carbonated magnesia.

The taste of acetite of magnesia, is sweet, with a slight mixture of bitter: by evaporation, it is reduced to a viscous syrupy consistence, incapable of being crystallized; but by further concentration, and subsequent cooling, becomes solid, and deliquescent in the air: it is totally soluble in spirit of wine, and from the ease with which it is decomposed, the affinity between its elements appears to be extremely weak. The alkalies, and the rest of the alkaline earths, most of the mineral, vegetable, and animal acids are capable of decomposing this salt by abstraction of its acid or earthy base. It is not made any use of.

Encyclop. Method. art. Acéte Magnésien. Pearson's Table of Affinity.

Acetite of Alumine. *Acétite d'Alumine. Aluminous mordant* of the calico-printers.

Of all the acetous salts this is the most important, being absolutely essential to the improved state of the arts of Dyeing and Calico-printing. It is not easy to prepare this salt directly, distilled vinegar, even when concentrated, having no perceptible action on clay; the fresh precipitated and washed earth of alum is indeed soluble by long digestion in a large excess of acetous acid; but the most economical and effectual way of producing the salt in question, is by means of the double affinities of common alum and sugar of lead. For this purpose, to a blood-warm solution of alum in rain-water, is first of all to be cautiously added a solution of pearlash, or any other sufficiently pure alkali, till the liquor is just upon the point of becoming turbid, in order to saturate the excess of acid in common alum; a cold saturated solution of acetite of lead (sugar of lead) in rain-water is then to be stirred in as long as any precipitation takes place; by standing a few hours, the sulphat of lead entirely subsides, and the supernatant clear liquor, containing acetite of alumine and potash, may be drawn off with a syphon. By washing the sediment with cold water a dilute solution of acetite of alumine is obtained, which may be used instead of water in dissolving alum for the next preparation of aluminous mordant.

Acetite of alumine thus prepared has an acetous strongly styptic taste: by gradual evaporation and cooling, it assumes the form of small needle-shaped crystals, which are exceeding deliquescent: by a heat inferior to that of boiling water, the acid is almost wholly driven off. It is decomposed by magnesia, and by all the substances that decompose acetite of magnesia. Its use is almost wholly confined to the dyers and calico-printers.

Encyclop. Method. art. Acéte Alumineux.

Acetite of Glycine. *Acétite de Glucine.*

This is an uncrystallizable salt, which by evaporation becomes of a gummy semiductile consistence; its taste is sweet, and very astringent, with a flavour of vinegar: its other properties have not been examined into; it is not applied to any use. B. la Grange, ii. 452.

For the *metallic acetites*, see the respective metals.

ACETIFICATION is used by some *Chemists* to denote the action or operation, by which vinegar is made. See *Acetous* Fermentation.

Acid

ACID, in *Chemiſtry*, is uſed in common language as a generic name for all thoſe ſubſtances which impreſs the organs of taſte with a ſharp ſour ſenſation. Since, however, there are certain bodies deſtitute of this property, which nevertheleſs are claſſed by all chemical writers as acids, this popular characteriſtic muſt be abandoned as eſſential, for one which is more comprehenſive.

Newton's well know definition of an acid, "that which "ſtrongly attracts, and is ſtrongly attracted," would have required notice only in the hiſtory of chemical opinions, if it had not been implicitly adopted by one of the ableſt chemiſts of the preſent age, Cit. Guyton Morveau. (Dict. Method. art. *acide*.) "Now if any one ſhould aſk me," ſays he "what "is an acid, I reply, it is that which of all palpable ſub-"ſtances is the moſt powerful ſolvent; that which acts on "the greateſt number of other bodies; that, as Newton has "ſo well expreſſed it, which ſtrongly attracts, and is "ſtrongly attracted." It is a greater fault for a definition to be too comprehenſive than too circumſcribed, and that which has been juſt quoted not only includes alkalies as well as acids, as indeed Morveau allows, but all the active chemical agents, ſuch as water, alcohol, hydrogen, oxygen, &c. for they are all powerful ſolvents, act on a great num-

ber

ber of other bodies, ſtrongly attract, and are ſtrongly attracted. In fact, there is no one property peculiar to the genus acid, and which belongs to each ſpecies, ſo that it is not poſſible to give a definition of the term: nevertheleſs, by combining together the general diſtinguiſhing qualities of acids, and noting at the ſame time the exceptions to theſe, a deſcription may be produced more illuſtrative than the moſt laboured definition.

Previouſly to the conſideration of the general properties of acids, it will be an advantage to give a ſketch of the opinions held by the old chemiſts concerning their origin and mode of action, and to examine more at large the theory of Lavoiſier upon the ſame ſubject.

When the mechanical ſyſtem was in vogue, according to which the chemical action of bodies was explained by the ſuppoſed figure and ſize of their reſpective moleculæ, acids were ſuppoſed to be a genus of ſalts, compoſed of extremely ſmall and ſharp ſpiculæ, which readily penetrated into the minuteſt pores of the ſubſtances ſubjected to their action, and thus ſeparated from each other their component parts; while, at the ſame time, the acid became neutralized by its points being ſheathed in the pores of the body with which it was mixed. This explanation was, however, ably controverted by Boyle, and by Stahl in his work on ſalts; and, at length, together with other chemical phenomena, the ſolvent power of acids was arranged by Macquer and his contemporaries, under the general laws of elective attraction.

After a few of the acids were diſcovered, it was ſuppoſed by Paracelſus, and ſeveral chemiſts of his age, that there exiſted an univerſal ſaline element, or principle of acidity common to all acids, which therefore differed from each other rather in mode than eſſence. Becher, though he allowed the unity of the cauſe of acidity, yet affirmed it to be compoſed of water and vitrifiable earth, and therefore not entitled to rank as an element. Stahl, in his valuable reſearches into the exiſtence of phlogiſton, and the compoſition of ſalts, was induced to believe that the ſulphuric acid, or as it was then called the vitriolic, was the original acid, of which all the reſt were only modifications. A ſimilar opinion was held by Sage and Landriani, except that the former ſuppoſed the phoſphoric acid, and the latter the carbonic acid, to be the primary one. The diſcovery of dephlogiſticated air, (oxygen gas) having been made by Prieſtley in 1774, a multitude of experiments were ſoon after inſtituted by the chemiſts of Europe on this intereſting ſubſtance; and, in 1778, a memoir was preſented to the royal academy of ſciences at Paris, by Lavoiſier, on the compoſition of the acid of ſugar. In this, after having deſcribed the method of preparing the acid of ſugar by means of nitrous acid, he concludes, that the converſion of nitrous acid into nitrous gas, is owing to the abſtraction of part of its oxygen by the ſuperior affinity of ſugar for this ſubſtance, and that the ſugar in conſequence of its union with oxygen acquires the properties of an acid. Proceeding afterwards to generalize this inference, he maintains that oxygen is the univerſal acidifying element, and that by combining in certain proportions with combuſtible baſes without decompoſing them, it thereby converts them into peculiar acids. This doctrine, ſimple and elegant, and plauſible as it was, did not however at firſt meet with general concurrence; but, in the courſe of the controverſy, it gradually acquired, and merited new advocates from the accumulated teſtimonies of experiment in its confirmation.—The publication of Lavoiſier's Elements of Chemiſtry, in 1789, contributed more than any thing elſe to ſettle the opinion of chemiſts upon the ſubject; in this work he demonſtrates that phoſphorus and charcoal, and ſulphur, being ſeparately inflamed in oxygen gas, combine with its baſe, acquire an additional weight equivalent to that of the air conſumed, and are converted into the phoſphoric, carbonic, and ſulphuric acids.

Beſides the ſynthetical arguments above alluded to, the Lavoiſerian theory is ſupported by an equal number of analytical experiments, in which moſt of the known acids are decompoſed into oxygen, and one or more combuſtible baſes. The moſt elegant ſpecimen of both kinds of proof is furniſhed by the nitrous acid: if purified nitre, (nitrat of potaſh) previouſly deprived of its water of cryſtallization, be expoſed in a ſilver retort to a low red heat, a large quantity of gas, conſiſting of oxygen and azot, in the proportion of about 80 of the former to 20 of the latter, will be given out, and pure potaſh will remain in the retort, whoſe weight together with that of the gaſſes will be equivalent to that of the original nitre; the mixed gaſſes are wholly deſtitute of acid properties, but by being forced into union by means of the electric ſpark, their volume is gradually diminiſhed, and at length the whole is reduced to an acid liquor, poſſeſſing all the qualities of nitrous acid; if this and the potaſh remaining in the firſt proceſs be mixed together, chemical union immediately enſues, and nitre is reproduced.

Three of the known acids are incapable of being decompoſed by any method that we are at preſent acquainted with; it is therefore only from analogy that they are ſuppoſed to contain oxygen for their acidifying principle; this circumſtance, however, is no peculiar objection to the theory of Lavoiſier, for ſince all the decompoſable acids may be reſolved into oxygen and a ſimple or compound combuſtible baſe, it ſeems conſiſtent with the principles of chemical philoſophy to eſtabliſh that as a general law, to which in the preſent ſtate of our knowledge, there is not a ſingle exception.

Subſtances, whoſe mutual affinity is conſiderable, may combine with each other in various proportions, and the reſulting compounds will vary in their properties accordingly: this is the caſe with all the known acidifiable baſes which in their loweſt ſtate of oxydation exhibit no acid properties whatever: nor is the developement of an acid an evidence of the compleat ſaturation of its baſe with oxygen, there being ſeveral acids capable of combining with additional quantities of oxygen, and thus acquiring new and more decided acid characters.—It is even ſuppoſed that ſome baſes may be oxygenated in three different degrees, preſerving in each the eſſential qualities of acids: hence reſults an important arrangement of acids according as they are oxygenated in the firſt, ſecond or third degree. The reformed chemical nomenclature on the principles of Lavoiſier and Morveau, has ingeniouſly diſtinguiſhed theſe ſtates by the terminations *ous* and *ic*, and the prefix *oxy* (for oxygenated); thus ſulphur, at the loweſt ſtate of oxygenation in which it acquires acid properties, is called *ſulphureous acid*; when ſtill further oxygenated it becomes *ſulphuric acid*; thus alſo, muriatic acid, when raiſed to the third degree of oxygenation, becomes *oxy-muriatic acid.*

The old chemiſts divided acids into mineral, vegetable, and animal, according to their ſuppoſed origin; this, however, is not only an inconvenient, but an incorrect method of arrangement, as many of theſe bodies are found in all the three natural kingdoms. Upon the whole, perhaps, the beſt way of arranging them is the following:

States of Oxygenation.

	Baſes.	1ſt.	2d.	3d.
With ſimple radicals.	*Sulphur* -	Sulphureous -	Sulphuric	
	Azot -	Nitrous -	Nitric	
	Phoſphorus -	Phoſphoreous -	Phoſphoric	
	Carbon -	- - - -	Carbonic	
	Arſenic -	Arſenious	Arſenic	
	Molybdena	- - - -	Molybdic	
	Chrome -	- - - -	Chromic	
With double radicals.	*Carbon* and *Hydrogen* in different proportions.	Acetous -	Acetic	
			Tartaric	
			Citric	
			Oxalic	
			Malic	
			Gallic	
			Benzoic	
			Succinic	
			Saccholactic	
			Formic	
			Sebacic ?	
With triple radicals.	*Carbon, Hydrogen,* and *Azot.*		Pruſſic	
			Lithic	
With unknown radicals.			Muriatic -	Oxymuriatic
			Fluoric	
			Boracic	

The chemiſts of the laſt century ſeem to have been acquainted only with the three mineral acids, as they are called, viz. the ſulphuric, nitric, and muriatic, and with the acetous acid or vinegar: the accuracy and induſtry of the moderns have increaſed the number of ſpecies to twenty-nine; how many more may be hereafter added to the liſt it is impoſſible to aſcertain. Without adverting to the poſſibility of diſcovering new acidifiable baſes, it is by no means improbable, however, that many of the ſimple combuſtible bodies as the metals, or the compound ones as phoſphorated hydrogen, ſulphurated hydrogen, the metallic phoſphurets, &c. may be ſo far ſaturated with oxygen, as to become peculiar acids.

The characteriſtic properties of acids, *i. e.* the peculiar laws and effects of their action on other chemical ſubſtances, yet remain to be mentioned.

1. When taken into the mouth they occaſion a ſour taſte.

The oxymuriatic acid alone is deſtitute of this property; the reſt poſſeſs it in a greater or leſs degree according to their liquid or ſolid form, and the energy with which they act on the animal fibre, from the corroſive and intenſely ſour ſulphuric acid, to the boracic, whoſe taſte can ſcarcely be perceived.

2. They change native vegetable blues to red.

Indigo is not turned red by any acid, nor does turneſol paper yield to ſome of the weakeſt ones, but both theſe pigments are artificial: the ſulphureous and oxymuriatic acid diſcharge entirely the native vegetable blues, not however before having changed them to red.

3. They have a ſtronger affinity for alkalies than theſe have for any other ſubſtance. Therefore, all the ſoluble combinations of alkalies with metallic oxyds, with earths, with ſulphur, &c. are decompoſed by any acid.

4. They combine with earths, with alkalies, and with metallic oxyds, forming the numerous and very important claſſes of earthy, neutral, and metallic ſalts, moſt of which are ſuſceptible of cryſtallization.

5. The property of incombuſtibility has been generally attributed to acids as a characteriſtic, but certainly very *erroneouſly. The moſt incombuſtible* of the acids are no more ſo than the fixed alkalies, the earths, and the perfect metallic oxyds; and all the acids with two or three radicals, and thoſe with ſimple radicals in the firſt ſtate of oxygenation, are, ſtrictly ſpeaking, combuſtible, that is, they unite at a certain temperature with oxygen gas, during which combination heat, and in ſome caſes light alſo, are extricated.

The medical effects of acids are conſiderable, and vary according to their degree of concentration; the moſt active, when pure, or nearly ſo, are uſed externally as cauſtics and eſcharotics, and as powerful ſtimulants in ſome caſes of palſy: if largely diluted with water, they may be ſafely employed internally in fevers, inflammations, and hemorrhages, as refrigerants and aſtringents.

For the particular acids, ſee them under their ſpecific names.

Encycloped. Method. art. Acide.—Lavoiſier's Elements of Chemiſtry.—Prieſtley on Air, vol. ii.—Fourcroy, Syſteme des Connoiſ. Chimiq. vol. ii.—Macquer's Chem. Dict. art. Acid. Cullen Mat. Med. vol. ii.

Aerostation

AEROSTATION, formed of *ἀὴρ*, and *στατικὴ*, of *ἵστημι*, *I weigh*, the *science of weights*, in its primary and proper sense, denotes the science of weights, suspended in the air; but in the modern application of the term, it signifies the art of navigation through the air, both in the principles and the practice of it. Hence also the machines, which are employed for this purpose, are called *aerostats*, or *aerostatic* machines; and, on account of their round figure, *air-balloons*. The *aeronaut*, formed of *ἀὴρ* and *ναύτης*, *sailor*, is the person who navigates through the air by means of such machines.

Aerostation, *principles of.* The fundamental principles of this art have been long and generally known; although the application of them to practice seems to be altogether a modern discovery. They are particularly illustrated in this Dictionary under the articles *Weight of* Air, *Elasticity of* Air, and *Specific* Gravity.

It will be sufficient, therefore, to observe in this place, that any body, which is specifically, or bulk for bulk, lighter than the atmospheric air encompassing the earth, will be buoyed up by it, and ascend; but as the density of the atmosphere decreases, on account of the diminished pressure of the superincumbent air, and the elastic property which it possesses, at different elevations above the earth, this body can rise only to a height in which the surrounding air will be of the same specific gravity with itself. In this situation it will either float, or be driven in the direction of the wind or current of air, to which it is exposed. An air-balloon is a body of this kind, the whole mass of which, including its covering and contents, and the several weights annexed to it, is of less specific gravity than that of the air in which it rises.

Heat is well known to rarefy and expand, and consequently to lessen the specific gravity of the air to which it is applied; and the diminution of its weight is proportional to the heat. To the observations that occur under *Elasticity of* Air to this purpose, we shall here add, that one degree of heat, according to the scale of Fahrenheit's thermometer, seems to expand the air about one four hundredth part; and about 400, or rather 435, degrees of heat, will just double the bulk of a quantity of air. If, therefore, the air inclosed in any kind of covering be heated, and consequently dilated, to such a degree, as that the excess of the weight of an equal bulk of common air above the weight of the heated air, is greater than the weight of the covering and its appendages, this whole mass will ascend in the atmosphere, till, by the cooling and condensation of the included air, or the diminished density of the surrounding air, it becomes of the same specific gravity with the air in which it floats; and without renewed heat, it will gradually descend.

If, instead of heating common air inclosed in any covering, and thus diminishing its weight, the covering be filled with an elastic fluid, lighter than atmospheric air; so that the excess of the weight of an equal bulk of the latter above that of the inclosed elastic fluid be greater than the weight of the covering and its appendages, the whole mass will in this case ascend in the atmosphere, and continue to rise till it attains a height at which the surrounding air is of the same specific gravity with itself. Inflammable air is a fluid of this kind. For the knowledge of many of its properties, we are indebted to Mr. Henry Cavendish: who discovered, that if common air is eight hundred times lighter than water, inflammable air is seven times lighter than common air; but if common air is eight hundred and fifty times lighter than water, then inflammable air is 10,8 times lighter than common air. See Phil. Trans. vol. lvi. art. 19. and *Inflammable* Air or Hydrogen.

The construction of air-balloons depends upon the principles above stated; and they are of two kinds, as one or the other of the preceding methods of preparing them is adopted.

Aerostation, *history of.* In the various schemes that have

have been propofed for navigating through the air, fome have had recourfe to artificial wings; which, being conftructed like thofe of birds, and annexed to the human body, might bear it up, and by their motion, produced either by mechanical fprings, or mufcular exertion, effect its progrefs in any direction at pleafure. This is one of the methods of artificial flying fuggefted by bifhop Wilkins, in the feventh chapter of his Dedalus, or Treatife on Mechanical Motions; but the fuccefs of it is doubtful, and experiments made in this way have been few and unfatisfactory. Borelli (De Motu Animalium, cap. 22. prop. 193 and 204, p. 196 and 208, ed. 1710), having compared the power of the mufcles which act on the wings of a bird with that of the mufcles of the breaft and arms of a man, finds the latter altogether infufficient to produce, by means of any wings, that motion againft the air, which is neceffary to raife a man in the atmofphere.

Others, with greater probability of fuccefs, have propofed to attach the human body to fome mafs, which being lighter than air, might raife itfelf and the annexed weight into the regions of that element. This method has actually fucceeded; though Borelli (*ubi fupra*), as well as Leibnitz, denied the poffibility of a man's flying by any of the means with which they were acquainted.

It is needlefs to recite any of the accounts relating to this fubject, which have been tranfmitted to us by the ancients. Moft, if not all of them, are fabulous. An ingenious writer, in a work cited at the clofe of this article, has given us the refult of his enquiries into the records of antiquity; and he informs us, that the earlieft account of any thing relating to flying, which has the appearance of authenticity, is that of the wooden pigeon, conftructed by Archytas in the fourth century, before the Chriftian æra, and of which Aulus Gellius (Noctes Atticæ, lib. x. cap. 12.) relates, that it could fly by means of mechanical powers, and by an inclofed fpirit. This fpirit, or aura, our author apprehends, was nothing more than a fort of animation, which the machine appeared to be poffeffed of, in confequence of its extraordinary mechanifm. Aeroftation was, therefore, a fubject either altogether unknown, or very imperfectly underftood among the ancients; unlefs we fuppofe it to be one of thofe arts, of which the records are loft. In later times, the fchemes which have been propofed by ingenious men feem to have terminated in fpeculation. The reader will find a brief account of fome of them under the articles Atmosphere and *Artificial* Flying, and a more comprehenfive hiftory of the projects and atchievements of different perfons, in the work cited below. Upon the whole it appears, that the art of traverfing the air is an invention of our own time; and the whole hiftory of it is comprehended within a very fhort period.

Soon after Mr. Cavendifh's difcovery of the fpecific gravity of inflammable air, it occurred to the ingenious Dr. Black of Edinburgh, that if a bladder, fufficiently light and thin, were filled with this air, it would form a mafs lighter than the fame bulk of atmofpheric air, and rife in it. This thought was fuggefted in his lectures in 1767 or 1768; and he propofed, by means of the allantois of a calf, to try the experiment. Other employments, however, prevented the execution of his defign. The poffibility of conftructing a veffel, which, when filled with inflammable air, would afcend in the atmofphere, had occurred alfo to Mr. Cavallo about the fame time; and to him belongs the honour of having firft made experiments on this fubject, in the beginning of the year 1782, of which an account was read to the Royal Society, on the 20th of June in that year. He tried bladders; but the thinneft of thefe, however fcraped and cleaned, were too heavy. In ufing China paper, he found that the inflammable air paffed through its pores, like water through a fieve; and having failed of fuccefs by blowing this air into a thick folution of gum, thick varnifhes, and oil paint, he was under a neceffity of being fatisfied with foap-balls, which, being inflated with inflammable air, by dipping the end of a fmall glafs tube, connected with a bladder containing the air, into a thick folution of foap, and gently compreffing the bladder, afcended rapidly in the atmofphere; and thefe were the firft fort of inflammable air-balloons that were ever made.

For balloons formed on a larger fcale, and on the principle of rarefied air, we muft direct our attention to France; where the two brothers, Stephen and Jofeph Montgolfier, paper-manufacturers at Annonay, about 36 miles from Lyons, diftinguifhed themfelves by exhibiting the firft of thofe aeroftatic machines, which have fince excited fo much attention and aftonifhment. The firft idea of fuch a machine was fuggefted to them by the natural afcent of the fmoke and clouds in the atmofphere; and the firft experiment was made at Avignon by Stephen, the eldeft of the two brothers, towards the middle of November, 1782. Having prepared a bag of fine filk, in the fhape of a parallelepipedon, and in capacity about forty cubic feet, he applied to its aperture burning paper, which rarefied the air, and thus formed a kind of cloud in the bag; and when it became fufficiently expanded, it afcended rapidly to the cieling. Soon afterwards the experiment was repeated by the two brothers at Annonay, in the open air, when the machine afcended to the height of about feventy feet. Encouraged by their fuccefs, they conftructed a machine, the capacity of which was about 650 cubic feet; which, in the experiment, broke the ropes that confined it, and after afcending rapidly to the height of about 600 feet, fell on the adjoining ground. With another machine, 35 feet in diameter, they repeated the experiment in April, 1783; when breaking loofe from its confinement, it rofe to the height of above 1000 feet, and being carried by the wind, it fell at the diftance of about three quarters of a mile from the place where it afcended. The capacity of this machine was equal to about 23,430 cubic feet; and when inflated, it meafured 117 Englifh feet in circumference. The covering of it was formed of linen, lined with paper; its fhape was nearly fpherical; and its aperture was fixed to a wooden frame about 16 feet in furface. When filled with vapour, which was conjectured to be about half as heavy as common air, it was capable of lifting up about 490 pounds, befides its own weight, which, together with that of the wooden frame, was equal to 500 pounds. With this machine the next experiment was performed at Annonay, on the 5th of June, 1783, before a great multitude of fpectators. The flaccid bag was fufpended on a pole 35 feet high; ftraw and chopped wool were burnt under the opening at the bottom; the vapour, or rather fmoke, foon inflated the bag, fo as to diftend it in all its parts; and this immenfe mafs afcended in the air with fuch a velocity, that in lefs than 10 minutes it reached the height of about 6000 feet. A breeze carried it in an horizontal direction to the diftance of 7668 feet; and it then fell gently on the ground. Mr. Montgolfier attributed the afcent of the machine, not to the rarefaction of the heated air, which is the true caufe, but to a certain gas or aeriform fluid, fpecifically lighter than common air, which was fuppofed to be difengaged from burning fubftances, and which

has been commonly called Montgolfier's gas, as balloons of this kind have been denominated *Montgolfiers*.

As soon as the news of this experiment reached Paris, the philosophers of the city, conceiving that a new sort of gas, half as heavy as common air, had been discovered by Messrs. Montgolfier, and knowing that the weight of inflammable air was not more than the eighth or tenth part of the weight of common air, justly concluded that inflammable air would answer the purpose of this experiment better than the gas of Montgolfier, and resolved to make trial of it. A subscription was opened by M. Faujas de St. Fond towards defraying the expence of the experiment. A sufficient sum of money having been soon raised, Messrs. Roberts were appointed to construct the machine; and M. Charles, professor of experimental philosophy, to superintend the work. After surmounting many difficulties in obtaining a sufficient quantity of inflammable air, and finding a substance light enough for the covering, they at length constructed a globe of lutestring, which was rendered impervious to the inclosed air by a varnish of elastic gum or CAOUTCHOUC, dissolved in some kind of spirit or essential oil. The diameter of this globe, which from its shape was denominated a balloon, was about thirteen feet, and it had only one aperture, like a bladder, to which a stop-cock was adapted: its weight, when empty, together with that of the stop-cock, was 25 pounds. On the 23d of August, 1783, they began to fill the globe with inflammable air; but this, being their first attempt, was attended with many hindrances and disappointments. At last, however, it was prepared for exhibition; and on the 27th it was carried to the Champ de Mars, where, being disengaged from the cords that held it down, it rose before a prodigious concourse of people, in less than two minutes, to the height of 3123 feet. It then entered a cloud, but soon appeared again; and at last it was lost among other clouds. This balloon, after having floated about three quarters of an hour, fell in a field about fifteen miles distant from the place of ascent; where, as we may naturally imagine, it occasioned much astonishment to the peasants. Its fall was owing to a rent, occasioned by the expansion of the inflammable air in that rare part of the atmosphere to which it ascended. When the balloon went up, its specific gravity was 35 pounds less than that of common air.

In consequence of this brilliant experiment, many balloons were made on a small scale; gold-beaters skin was used for the covering; and their size was from 9 to 18 inches in diameter.

Mr. Montgolfier repeated an experiment with a machine of his construction before the commissaries of the Academy of Sciences on the 11th and 12th of September. This machine was 74 feet high, and about 43 feet in diameter. When distended, it appeared spheroidical. It was made of canvas, covered with paper, both within and without; and it weighed 1000 pounds.

The operation of filling it with rarefied air, produced by means of the combustion of 50 pounds of dry straw, and 12 pounds of chopped wool, was performed in about nine minutes; and its force of ascension, when inflated, was so great that it raised eight men who held it some feet from the ground. This machine was so much damaged by the rain, that it was found necessary to prepare another for exhibition before the king and royal family on the 19th. This new machine consisted of cloth, made of linen and cotton thread, and was painted with water-colours both within and without. Its height was near 60 feet, and its diameter about 43 feet. Having made the necessary preparations for inflating it, the operation was begun about one o'clock on the 19th of September, before the king and queen, the court, and all the Parisians who could procure a conveyance to Versailles. In eleven minutes it was sufficiently distended, and the ropes being cut, it ascended, bearing up with it a wicker cage, in which were a sheep, a cock, and a duck. Its power of ascension, or the weight by which it was lighter than an equal bulk of common air, allowing for the cage and animals, was 696 pounds.

This balloon rose to the height of about 1440 feet; and being driven by the wind, it descended gradually and fell gently into a wood, at the distance of 10,200 feet from Versailles. After remaining in the atmosphere eight minutes, the animals in the cage were safely landed. The sheep was found feeding; the cock had received some hurt on one of his wings, probably from a kick of the sheep; the duck was perfectly well.

The success of this experiment induced M. Pilatre de Rozier, with a philosophical intrepidity which will be recorded with applause in the history of aerostation, to offer himself as the first adventurer in this aerial navigation. Mr. Montgolfier constructed a new machine for this purpose in a garden in the Fauxbourg St. Antoine. Its shape was oval; its diameter being about 48 feet, and its height about 74 feet. To the aperture at the bottom was annexed a wicker gallery about three feet broad, with a ballustrade about three feet high. From the middle of the aperture was suspended by chains, which came down from the sides of the machine, an iron grate or brazier, in which a fire was lighted for inflating the machine; and port-holes were opened in the gallery, towards the aperture, through which any person, who might venture to ascend, might feed the fire on the grate with fuel, and regulate the dilatation of the inclosed air of the machine at pleasure. The weight of this aerostat was upwards of 1600 pounds. On the 15th of October, the fire being lighted and the machine inflated, M. P. de Rozier placed himself in the gallery, and ascended, to the astonishment of a multitude of spectators, to the height of 84 feet from the ground, and there kept the machine afloat during 4′ 25″, by repeatedly throwing straw and wool upon the fire: the machine then descended gradually and gently, through a medium of increasing density, to the ground; and the intrepid adventurer assured the spectators that he had not experienced the least inconvenience in this aerial excursion. This experiment was repeated on the 17th, and on the 19th, when M. P. de Rozier, in his descent, and in order to avoid danger by reascending, evinced to a multitude of observers, that the machine may be made to ascend and descend at the pleasure of the aeronaut, by merely increasing or diminishing the fire in the grate. The balloon having been hauled down, M. Giraud de Villette placed himself in the gallery opposite to M. Rozier; and being suffered to ascend, it hovered for about nine minutes over Paris in the sight of all its inhabitants at the height of about 330 feet. In another experiment the marquis of Arlandes ascended with M. Rozier much in the same manner. In consequence of the report of the preceding experiment, signed by the commissaries of the Academy of Sciences, it was ordered that the annual prize of 600 livres should be given to Messrs. Montgolfier for the year 1783. In the experiments above recited the machine was secured by ropes: but they were soon succeeded by unconfined aerial navigation. Accordingly the balloon of 74 feet in height, above mentioned, was removed to La Muette, a royal palace in the Bois de Boulogne: and all things being ready, on the 21st of November M. P. de

Rozier and the marquis d'Arlandes took their respective posts in the gallery, and at 54 minutes after one the machine was absolutely abandoned to the element, and ascended calmly and majestically in the atmosphere. The aeronauts, having reached the height of about 280 feet, waved their hats to the astonished multitude: but they soon rose too high to be distinguished, and are thought to have soared to an elevation of above 3000 feet. They were at first driven by a north-west wind horizontally over the river Seine and over Paris, taking care to clear the steeples and high buildings by increasing the fire; and in rising met with a current of air, which carried them southward. Having passed the Boulevard, and desisting from supplying the fire with fuel, they descended very gently in a field beyond the new Boulevard, about 9000 yards distant f om the palace de la Muette. They were in the air about 25 minutes. The weight of the whole apparatus, including that of the two travellers, was between 1600 and 1700 pounds.

Notwithstanding the rapid progress of aerostation in France, we have no authentic account of any aerostatic experiments performed in other countries till about the close of the year 1783. The first experiment of this kind, publicly exhibited in our own country, was performed in London on the 25th of November, by count Zambeccari, an ingenious Italian, with a balloon of oil silk, 10 feet in diameter, and weighing 11 pounds. It was gilt, in order to render it more beautiful and more impermeable to the inflammable air. This balloon, three-fourths of which were filled with inflammable air, was launched from the Artillery-ground, in the presence of a vast concourse of spectators, at one o'clock in the afternoon, and at half past three was taken up near Petworth, in Sussex, 48 miles distant from London; so that it travelled at the rate of near 20 miles an hour. Its descent was occasioned by a rent, which must have been the effect of the rarefaction of the inflammable air, when the balloon ascended to the rarer part of the atmosphere.

The Parisian philosophers having concerted and executed the first aerial voyage with a balloon inflated by heated air, determined to attempt a similar voyage with a balloon filled with inflammable air, which seemed to be preferable to dilated air in every respect, the expence attending it excepted. A subscription was opened to defray the charges, which were estimated at about ten thousand livres; and the balloon was constructed by Messrs. Roberts, of gores of silk, varnished with a solution of elastic gum. Its form was spherical, and it measured $27\frac{1}{2}$ feet in diameter. The upper hemisphere was covered by a net, which was fastened to the hoop encircling its middle, and called its equator. To this equator was suspended by ropes a car or boat, covered with painted linen and beautifully ornamented, which swung a few feet below the balloon. In order to prevent the bursting of the machine by the expansion of the inflammable air in a rarefied medium, it was furnished with a valve, which might be opened by means of a string annexed to it, for the discharge of part of the internal air without admitting the external to enter. To this balloon was likewise annexed a long pipe through which it was filled. The apparatus for filling it consisted of several casks placed round a large tub of water, each of which had a long tin tube, terminating under a vessel or funnel, that was inverted into the water of the tub. A tube proceeding from this funnel, communicated with the balloon, which stood just over it. Iron filings and diluted vitriolic acid were put into the casks; and the inflammable air, produced from these materials, passed through the tin tubes, through the water of the tub, and through the funnel of the balloon. The car was ballasted with sand-bags; so that by letting some of the air escape through the valve they might descend, and by discharging some of their ballast ascend. The specific gravity of the inflammable air, with which the balloon was filled, was to that of common air nearly as 1 to $5\frac{1}{4}$, and the balloon's power of ascension, when filled for the experiment and when actually ascending, was twenty pounds. The weight of the balloon and of its various appendages was $604\frac{1}{2}$ pounds, and therefore the weight sustained by the inflammable air was $624\frac{1}{2}$ pounds: and if from the weight of the common air displaced, which was found to be $771\frac{1}{4}$ pounds, the former be subtracted, there will remain 147 pounds for the real weight of the inflammable air contained in the balloon.

The 1st of December was fixed upon for the display of this grand experiment; and every precaution was made for conducting it with advantage. The garden of the Thuilleries was the scene of operation; and it was crowded and encompassed with an innumerable multitude of observers. Signals were given by the firing of cannon, waving of pendants, &c. A small *Montgolfier* was launched for shewing the direction of the wind, and for the amusement of the people, previously to the general display. At three quarters after one o'clock, M. Charles and one of the Roberts, having seated themselves in the boat attached to the balloon, and furnished with proper instruments, provisions, and cloathing, left the ground, and ascended with a moderately accelerated velocity to the height of about 600 yards; the surrounding multitude standing silent with fear and amazement. At this height the aerial navigators made signals of their safety. When they went up, the thermometer, according to Fahrenheit's scale, stood at 59°; and the barometer at 30, 18 inches. At the height to which they ascended the barometer stood at 27 inches, whence they deduced their elevation to be nearly 600 yards. During the rest of the voyage the quicksilver in the barometer was generally between 27 and 27, 65 inches, rising and falling as part of the ballast was thrown out or some of the inflammable air escaped from the balloon. The thermometer generally stood between 53 and 57°. Soon after their ascent, they remained stationary for some time: they then moved horizontally in the direction of N. N. W. and having crossed the Seine, and passed over several towns and villages, to the great astonishment of the inhabitants, they descended in a field about 27 miles distant from Paris at a quarter past three o'clock; so that they had travelled at the rate of about fifteen miles an hour, without feeling the least inconvenience. The balloon still containing a considerable quantity of inflammable air, M. Charles re-ascended alone. In ten minutes he thought himself at the elevation of about 1500 toises. The globe, being now in a rarefied medium, swelled considerably; but when some of the inflammable air was discharged, it rose still higher. The barometer, which at his departure stood at 28 inches four lines, had now fallen to 18 inches ten lines. The thermometer, from about 47° of Fahrenheit's scale, had sunk to 21°. From these data the elevation of the globe was estimated at 1524 toises, or about 3,100 yards. M. de Meunier supposes that he ascended to the height of at least 3500 yards. He continued in the air about 33 minutes, and by occasionally pulling the string of the upper valve, and thus letting out the gas, he descended about three miles from the place of his ascent. All the inconvenience he experienced in his elevation was a dry sharp cold, with a pain in one of his ears and a part of his face, which he ascribed to the dilatation of the internal air. The small balloon, launched by M. Montgolfier, was found to have moved in a direction opposite to that of the aeronauts; whence it is inferred,

that there were two currents of air at different heights above the earth.

In the month of December of this year, feveral experiments with balloons were made at Philadelphia, in America, by Meffrs. Rittenhoufe and Hopkins. They contrived to connect feveral fmall balloons together, and thus they enabled a man to afcend to the height of 100 feet, and to float to a confiderable diftance. But fear induced him to cut open the balloons, and thus to defcend. Small balloons were at this time very common, both in France and England.

In January 1784, Mr. J. Montgolfier, accompanied by fix other perfons, afcended at Lyons, with a large rarefied air-balloon, 131 feet high, and 104 feet diameter, to the height of about 1000 yards. This was the largeft machine that had hitherto been made. It was formed of a double covering of linen, with three layers of paper between, and ftrengthened with ftrings and ribbons. It contained about 540,000 cubic feet of igneous gas; and its weight, including the gallery and paffengers, was 1600 pounds. After remaining in the air about fifteen minutes, a rent in the machine occafioned its fall: and when it came within about 600 feet of the ground, it defcended with a degree of celerity which very much alarmed the fpectators; but they all landed without injury.

On the 22d of February an inflammable air-balloon about five feet in diameter, was launched from Sandwich in Kent, which, travelling at the rate of about 30 miles an hour, croffed the Englifh Channel, and defcended in a field about nine miles from Lifle, in French Flanders.

The firft perfon in Italy, who was at the expence of conftructing an aeroftatic machine for making an aerial voyage, was the chevalier Paul Andreani of Milan: his machine was fpherical, about 68 feet in diameter, and formed upon the principle of thofe of Montgolfier. The chevalier, and two brothers of the name of Gerli, who had affifted in the conftruction of it, afcended, on the 25th of February, to the height of about 1200 feet; and they remained in the atmofphere about twenty minutes.

From the calculations made refpecting the capacity of this machine, it appears, that the included air was not rarefied above one-third, or that the included warm air was not lefs than two-thirds of that which would have filled the machine, when of the fame temperature with the external air; and this is the utmoft degree of rarefaction that can be reafonably expected in balloons of this kind.

The next aerial voyage was performed by M. Jean Pierre Blanchard, who had for feveral years been employed, though without fuccefs, in attempts of flying by mechanical contrivances. This voyage was performed in March 1784, with a balloon 27 feet in diameter, to which a boat was fufpended, with two wings and a rudder annexed to the boat, and a large umbrella or parachute fpread horizontally between the boat and the balloon, defigned to check the fall provided that the balloon fhould burft. The greateft altitude to which Mr. Blanchard afcended from the Champ de Mars at Paris, is fuppofed to be 9591 feet; and it appears from his own acknowledgment that the wings and rudder of his boat had little, if any, power in guiding the balloon from the direction of the wind. He was in the air an hour and a quarter, and defcended at Billancourt, near Seve, after having experienced heat, cold, hunger, and an exceffive drowfinefs.

Aeroftatic experiments and aerial voyages became fo frequent in the courfe of the year 1784, that the limits of this article will not allow our particularly recording them. We fhall, therefore, merely mention thofe which were attended with any peculiar circumftances. Meffrs. de Morveau and Bertrand afcended from Dijon in April, to the height of about 13000 feet, with an inflammable air balloon; the thermometer was obferved to ftand at 25 degrees. They were in the air during one hour and 25 minutes, and went to the diftance of about 18 miles. Their ears were affected in the manner defcribed by Mr. Charles. The clouds floated beneath them, and fecluded them from the earth: and they jointly repeated the motto infcribed on their aeroftat:—"Surgit nunc gallus ad æthera."

In May, four ladies and two gentlemen afcended with a Montgolfier at Paris above the higheft buildings; the machine was confined by ropes. It was 74 feet high, and 72 in diameter.

In a fecond voyage performed by Mr. Blanchard from Rouen, in May, it was obferved, that his wings and oars could not carry him in any other direction than that of the wind. The mercury in the barometer defcended as low as 20,57 inches; but on the earth, before he afcended, it ftood at 30,16 inches.

At Lyons, on the 4th of June, M. Fleurant and Madame Thible, the firft lady that made an aerial voyage, afcended in the prefence of Guftavus king of Sweden to the height of 8500 feet, and floated to the diftance of about two miles in 45 minutes.

A balloon, 32½ feet in diameter, filled with inflammable air, extracted from zinc, was raifed at Nantes on the 14th of June with two perfons, *viz.* M. Couftard de Maffi and M. Mouchet; which afcended to a great height, and in 58 minutes travelled to the diftance of 27 miles.

On the 23d of June a large aeroftat, on the principle of rarefied air, 91½ feet high and 79 feet in diameter, was elevated by Montgolfier at Verfailles, in the prefence of the royal family and the king of Sweden. M. Pilatre de Rozier and M. Prouft, afcended with it, and continued for 28 minutes at the height of 11732 feet and obferved the clouds below them, that reflected to the region which they occupied the rays of the fun; the temperature of the air being 5° below the freezing point; and in three quarters of an hour they travelled to the diftance of 36 miles. In confequence of this experiment the king granted to M. Rozier a penfion of 2000 livres.

On the 15th of July the duke of Chartres, the two brothers Roberts, and another perfon, afcended with an inflammable air-balloon of an oblong form, 55½ feet long and 34 feet in diameter, from the Park of St. Cloud: the machine remained in the atmofphere about 45 minutes. This machine contained an interior fmall balloon, filled with common air, by which means it was propofed to make it afcend or defcend without any lofs of inflammable air or ballaft. The boat was furnifhed with a helm and oars, intended for guiding it. At the place of departure the barometer ftood at 30, 12 inches. Three minutes after afcending, the balloon was loft in the clouds and involved in a denfe vapour. An agitation of the air, refembling a whirlwind, alarmed the aerial voyagers, and occafioned feveral fhocks, which prevented their ufing any of the inftruments and contrivances prepared for the direction of the balloon. Other circumftances concurred to increafe their danger; and when the mercury, ftanding in the barometer at 24,36 inches, indicated their height to be about 5100 feet, they found it neceffary to make holes in the bottom for difcharging the inflammable air: and having made a rent of between feven and eight feet, they defcended very rapidly, and at laft came fafely to the ground.

On the 18th of July M. Blanchard, accompanied by a

Mr. Boby, made his third aerial voyage with the fame inflammable air-balloon, at Rouen; and afcended fo high as to make the mercury in the barometer fall 4,76 inches, and the thermometer 40°. In two hours and a quarter they floated 45 miles, or at the rate of twenty miles an hour. In this voyage Mr. Blanchard conceived, that by agitating the wings of his boat he could not only afcend and defcend, but move fideways againft the wind; but fubfequent trials do not feem to have eftablifhed this fact. The machine retained its air during the night, and feveral ladies amufed themfelves the next day, by afcending with it to the height of 80 feet, the length of the ropes to which it was attached.

In the courfe of this fummer two perfons, one in Spain, and another in America, were in danger of lofing their lives by afcending with rarefied air-machines. The former was fcorched by the machine's taking fire, and fo hurt by his fall, that his life was long defpaired of; and the latter was wafted againft the wall of a houfe, and fo entangled, that he fell from the height of about twenty feet, and the machine took fire, and was confumed.

In the month of Auguft, the Abbé Carnus, profeffor of philofophy, and M. Louchet, profeffor of belles lettres, afcended at Rodez, a town of Guienne in France, with an aeroftatic machine of 57 feet in diameter. The air was calm, and the machine did not travel farther than about 14,900 yards in 46 minutes; and the height to which it afcended was 3920 yards above the level of the town. The thermometer was 34 degrees lower than it was at the earth when they afcended. On examining the air in one of two bottles, which they had filled at their higheft elevation, they found that it contained a quarter lefs air than if it had been filled at about the level of the fea; and the air, tried by the teft of nitrous air, was found more pure than that near the furface of the earth.

The firft aerial voyage in England was performed in London, on the 15th of September, by Vincent Lunardi, a native of Italy. His balloon was made of oiled filk, painted in alternate ftripes of blue and red. Its diameter was 33 feet. From a net which went over about two-thirds of the balloon, defcended 45 cords to a hoop hanging below the balloon, and to which the gallery was attached. The balloon had no valve; and its neck, which terminated in the form of a pear, was the aperture through which the inflammable air was introduced, and through which it might be let out. The air for filling the balloon was produced from zinc by means of diluted vitriolic acid. Mr. Lunardi departed from the Artillery-ground at two o'clock; and with him were a dog, a cat, and a pigeon. After throwing out fome fand to clear the houfes, he afcended to a great height. The direction of his motion at firft was north-weft by weft; but as the balloon rofe higher, it fell into another current of air, which carried it nearly north. About half after three he defcended very near the ground, and landed the cat, which was almoft dead with cold: then rifing, he profecuted his voyage. He afcribes his defcent to the action of an oar; but as he was under the neceffity of throwing out ballaft in order to re-afcend, his defcent was more probably occafioned by the lofs of inflammable air. At ten minutes paft four he defcended on a meadow near Ware in Hertfordfhire. The only philofophical inftrument which he carried with him was a thermometer, which in the courfe of his voyage ftood as low as 29°, and he obferved that the drops of water which collected round the balloon were frozen.

The longeft and the moft interefting voyage, which was performed about this time, was that of Meffrs. Roberts and M. Collin Hullin at Paris, on the 19th of September. Their aeroftat was filled with inflammable air. Its diameter was 27½ feet, and its length 46½ feet, and it was made to float with its longeft part parallel to the horizon, with a boat of nearly 17 feet long attached to a net that went over it as far as its middle. To the boat were annexed wings or oars, in the form of an umbrella. At 12 o'clock they afcended with 450 pounds of ballaft, and after various manœuvres defcended at 40 minutes paft fix o'clock near Arras, in Artois, having ftill 200 pounds of their ballaft remaining in the boat. Having rifen about 1400 feet, they perceived ftormy clouds which they endeavoured to avoid; but the current of air was uniform from the height of 600 to 4200 feet. The barometer on the coaft of the fea was 29,61 inches, and funk to 23,94 inches. They found that by working with their oars, they accelerated their courfe. In the profecution of their voyage, which was 150 miles, they heard two claps of thunder; and the cold occafioned by the approach of ftormy clouds made the thermometer fall from 77° to 59°, and condenfed the inflammable air in the balloon, fo as to make it defcend very low. From fome experiments they concluded, that they were able by the ufe of two oars to deviate from the direction of the wind about 22°. But this experiment requires repetition, in order to afcertain with accuracy the effect here afcribed to oars.

The fecond aerial voyage in England was performed by Mr. Blanchard and M. Sheldon, profeffor of anatomy to the Royal Academy, the firft Englifhman who afcended with an aeroftatic machine. This experiment was performed at Chelfea on the 16th of October. The wings ufed on this occafion feemed to have produced no deviation in the machine's tracks from the direction of the wind. Mr. Blanchard, having landed his friend about the diftance of 14 miles from Chelfea, proceeded alone with different currents; and afcended fo high as to experience great difficulty of breathing: a pigeon alfo, which flew away from the boat, laboured for fome time with its wings, in order to fuftain itfelf in the rarefied air, and after wandering for a good while returned and refted on one fide of the boat. Mr. Blanchard perceiving the fea before him defcended near Rumfey, about 75 miles from London, having travelled at the rate of nearly 20 miles an hour.

On the 12th of October, Mr. Sadler, of Oxford, made a voyage of 14 miles from that place in 17 minutes, with an inflammable air balloon of his own contrivance and conftruction.

Mr. Blanchard's fifth aerial voyage was performed from London on the 30th of November, in company with Dr. J. Jefferies, a native of America. This voyage was about twenty-one miles. It does not appear that they derived any advantage from their oars in directing the courfe of the balloon.

On the 4th of January 1785, Mr. Harper afcended with an inflammable air-balloon from Birmingham: he went to the diftance of 50 miles in about an hour and a quarter, and found no inconveniencies befide fuch as might be expected from the changes of wet and cold, and a temporary deafnefs. The thermometer defcended from 40° to 28°.

On the 7th of January Mr. Blanchard, accompanied by Dr. Jefferies, departed with the balloon, which had carried him five times through the air, from Dover caftle towards the French coaft. In their paffage they were under a neceffity of throwing away every thing which they had with them in the boat, and to part even with their clothes, in order to prevent the balloon from falling into the fea: but

as they approached the land, it began to rise: and in two hours they reached the high grounds near Calais, and the balloon rising still higher over the land, they descended safely in the forest of Guiennes. In consequence of this voyage the king of France presented Mr. Blanchard with a gift of 12000 livres, and granted him a pension of 1200 livres a year. A bottle which was thrown out of the boat in the time of their danger, struck the water with such force, that the shock was heard at a considerable elevation, and sensibly felt on the car and balloon.

On the 19th of January Mr. Crosbie ascended at Dublin with an inflammable air balloon to a great height, and rose so rapidly as to be out of sight in 3½ minutes. By opening the valve he descended suddenly as he approached very near the sea. On the 23d of March Count Zambeccari and Admiral Sir Edward Vernon ascended at London, and sailed to Horsham in Sussex, at the distance of 35 miles, in less than an hour. At the height of about two miles, the barometer having fallen from 30. 4 inches to 20. 8 inches, an accident endangered them, and obliged them to descend. In their descent they passed through a dense cloud, which covered them with snow. They observed that the balloon revolved perpetually round its vertical axis, with such rapidity as to perform each revolution in four or five seconds; they also mention a kind of rustling noise, which they heard among the clouds, and that the balloon was greatly agitated in its descent. On the 5th of May, Mr. Sadler and Mr. Windham ascended at Moulsey Hurst; and were driven by a current of air towards the sea. They fortunately descended at the conflux of the Thames and Medway; but the cords of their machine being released, it instantly ascended and floated to a considerable distance, and was taken up by a trading vessel at sea, where it fell. On the 12th of May, Mr. Crosbie ascended at Dublin, but soon came down again with a velocity which alarmed the spectators. Upon his descent, Mr. M'Guire, a college youth, sprung into the machine, and was carried off by the ascending balloon towards the Channel; he at length fell into the sea, and was taken up by a boat dispatched for his relief, just when his strength was exhausted with swimming, and thus his life was saved.

The fate of M. P. de Rozier, the first aerial navigator, and of his companion M. Romain, has been much lamented. They ascended at Boulogne on the 15th of June, with an intention of crossing the Channel to England. Their machine consisted of a spherical balloon 37 feet in diameter, filled with inflammable air; and under this balloon was suspended a small Montgolfier, or fire-balloon, ten feet in diameter. This Montgolfier was designed for rarefying the atmospheric air, and thus diminishing the specific gravity of the whole apparatus. For the first twenty minutes they seemed to pursue the proper course; but the balloon seemed to be much inflated, and the aeronauts appeared anxious to descend. Soon however, when they were at the height of about three quarters of a mile, the whole apparatus was in flames, and the unfortunate adventurers fell to the ground, and were killed on the spot.

On the 19th of July Mr. Crosbie ascended at Dublin, with a view of crossing the Channel to England. To a wicker basket of a circular form, which he had substituted for the boat, he had affixed a number of bladders, for the purpose of rendering his gallery buoyant, in case of a disaster at sea. The height to which he ascended at one time was such, that by the intense cold his ink was frozen, and the mercury sunk into the ball of the thermometer. He himself was sick, and he felt a strong impression on the tympanum of his ears. At his utmost elevation he thought himself stationary; but on discharging some gas, he descended to a very rough current of air blowing to the north. He then entered a dense cloud, and experienced strong blasts of winds, with thunder and lightning, which brought him with rapidity towards the surface of the water. The water soon entered his car; the force of the wind plunged him into the ocean; and it was with difficulty that he put on his cork jacket. The bladders which he had prepared were now found of great use. The water, added to his own weight, served as ballast; and the balloon maintaining its poise, answered the purpose of a sail, by means of which, and a snatch-block to his car, he moved before the wind as regularly as a sailing vessel. He was at length overtaken by some vessels that were crowding sail after him, and conveyed to Dunleary, with the balloon towed after them. On the 22d of July, Major Money, who ascended at Norwich, was driven out to sea, and after having been blown about for about two hours, he dropped into the water. After much exertion for preserving his life, and when he was almost despairing of relief, he was taken up by a revenue cutter in a state of extreme weakness; having been struggling to keep himself above water for about seven hours. The longest voyage that had been hitherto made was performed by Mr. Blanchard towards the end of August. He ascended at Lisle, accompanied by the chevalier de L'Epinard, and traversed a distance of 300 miles before they descended. On this, as well as on other occasions, Mr. Blanchard made trial of a parachute, in the form of a large umbrella, which he contrived for breaking the fall in case of any accident. With this machine he let down a dog, which came to the ground gently, and unhurt.

On the 8th of September Mr. Baldwin ascended from the city of Chester, and performed an aerial voyage of 25 miles in two hours and a quarter. His greatest elevation was about a mile and an half, and he supposes that the velocity of his motion was sometimes at the rate of 30 miles an hour. He has published a circumstantial account of his voyage, described the appearances of the clouds as he passed through them, and annexed a variety of observations relating to aerostation, which render his treatise valuable and interesting to those who wish to acquaint themselves with this subject. It would be tedious to recount the aerial expeditions that were performed in various parts of our own country, as well as on the continent, in the whole course of the year 1785; more especially as they have afforded us no experiment or discovery of any peculiar importance. The most persevering aerial navigator has been Mr. Blanchard. In August 1788, he ascended at Brunswick for the thirty-second time. Within two years from the first discovery of this art of navigating the atmosphere, more than forty different persons performed the experiment without any material injury; and it may be justly questioned, says Mr. Cavallo, whether the first forty persons, who trusted themselves to the sea in boats, escaped so safely. The catastrophe that befel Rozier, and the unpleasant circumstances that have happened to some of the aeronauts in our own country, have been owing not so much to the principle of the art, as to want of judgment, or imprudent management in the conduct of it.

We shall close this abstract of the history of aerostation with the observations of a very competent judge on the respective advantages and disadvantages of balloons made with inflammable air, and of those that are raised by means of hot air, to the former of which he gives the preference. The principal comparative advantages of the rarefied air-balloons are, their being filled with little or no expence; their not requiring to be made of so expensive materials; and the com-

bustibles necessary to fill them being found almost every where, so that when the provision of fuel is exhausted, the aeronaut may descend and recruit his fuel, in order to proceed on his voyage. But they must be larger than balloons of the other sort, in order to take up the same weight; and the presence of fire is a continual trouble and a continual danger. Experience has, in many instances, evinced the disastrous consequences that have attended them. On the other hand, the inflammable air balloon must be made of a substance impermeable to the subtile gas; the gas itself cannot be produced without a considerable expence; and it is not easy to find the materials and apparatus necessary for the production of it in every place. Improvements, however, daily occur in the preparation of the coverings of these balloons, so as to render them nearly impermeable to the inflammable air: and it has been found that an inflammable air-balloon, 30 feet in diameter, may be so made as to sustain two persons and a considerable quantity of ballast in the air for more than 24 hours, when properly managed; and one man might possibly be supported by the same machine for three days.

Aerostation, *practice of*. The shape of the balloon is one of the first objects of consideration in the construction of this machine. As a sphere admits the greatest capacity under the least surface, the spherical figure, or that which approaches nearest to it, has been generally preferred. However, since bodies of this form oppose a greater surface to the air, and consequently a greater obstruction to the action of the oar or wings than those of some other form, and therefore cannot be so well guided in a calm, or in a course different from the direction of the wind, it has been proposed to construct balloons of a conical or oblong figure, and to make them proceed with their narrow end forward. Mr. Hoole, an ingenious writer, who is now publishing a translation of the works of Leeuwenhoek, in his Thoughts on the farther Improvement of Aerostation, suggests the shape of a fish as the most proper: the sharp head, under such a form, will serve to divide the resisting fluid, and open a passage, and the tail will serve as a rudder to steer its course. He also proposes to fix a seat for the traveller in the lower part of the body of the fish, or in the centre of gravity of the whole mass, so that the machine may be always horizontal, and that the impulse of any force used there may actuate the whole body. And he farther suggests, that the traveller should be furnished with instruments of sufficient surface to take hold of the air, and of sufficient strength to bear the whole exertion of his muscular force, analogous in their form and situation to the fins of fishes. But by adopting the oblong shape, the surface, and consequently the weight of the cover, must be augmented, in order to obtain the same lifting power with that of a sphere, both because its capacity will be less under the same surface, and because its capacity must be made greater in order to compensate for the augmentation of weight. Besides, an oblong machine cannot easily be kept with the smallest part forward in the atmosphere: and if it should turn sideways, as it probably might, the proposed advantage would thereby be lost: not to add, that accidental circumstances might occur which would endanger its overturning.

In order to expedite the calculations that relate to the construction of a balloon of a spherical form, it should be remembered, that the circumferences of spheres are as their diameters; their surfaces as the squares; and their solid contents as the cubes of the diameters. The proportion of the diameter to the circumference of a circle, *i. e.* 7 to 22, or 1 to $3\frac{1}{7}$, should be recollected; so that if the diameter of a balloon be 35 feet, its circumference will be 110 feet. If the diameter be multiplied by the circumference, the product will be the surface of the sphere; *i. e.* $35 \times 110 = 3850$ square feet. If this surface be divided by the breadth (in feet) of the stuff of which the balloon is made, the quotient will be the number of feet in length necessary for constructing the balloon: thus if the stuff be 3 feet wide, $\frac{3850}{3} = 1283\frac{1}{3}$ feet, or 428 yards nearly, which is the quantity for a balloon of 35 feet in diameter. By knowing the weight of a given piece of the stuff, as of a square yard or square foot, it is easy to find the weight of the whole bag, by multiplying the surface in square feet or yards by the weight of a square foot or yard; *e. g.* if each square yard weigh 16 ounces, or one pound, the whole bag will weigh 428 pounds. Again, the capacity, or solid content of the sphere, may be found by multiplying $\frac{1}{6}$ of the surface by the diameter, or by taking $\frac{11}{21}$ of the cube of the diameter; thus, in the present instance, we shall have 22458 cubic feet for the capacity of the balloon, or the number of cubic feet of air which it will displace. From the content and surface of the balloon, we may deduce its power of ascension or levity in the following manner:—a cubic foot of air weighs, at an average, about $1\frac{1}{5}$ ounce, and adding to the number 22458, its fifth part, we shall have 26950 ounces, or 1684 pounds, for the weight of the common air displaced by the balloon. From this weight, deducting the weight of the bag, or 428 pounds, there will remain 1256 pounds expressing the levity of the balloon, independently of the contained air. If this be inflammable air, its weight varies from $\frac{1}{4}$ to $\frac{1}{11}$ the weight of common air; if it be taken at $\frac{1}{6}$ of the weight of common air, then $\frac{1684}{6} = 280$ pounds will denote the weight of the air filling the balloon; and taking this from 1256, *i. e.* $1256 - 280$, will leave 976 pounds, the power of ascension of the balloon, or the weight which it will carry up, consisting of the car, ropes, passengers, ballast, and other necessaries. If heated air be used, the density of this is diminished about one-third; and therefore, taking from 1684 one-third of itself, there will remain 1123 for the weight of the contained warm air, and this subtracted from 1256, leaves 133 pounds for the levity of the balloon; but as this is not sufficient for carrying up the car, passengers, &c. it is evident that a larger balloon, on Montgolfier's principle, is necessary for the same purpose that may be effected by a smaller one of inflammable air. To estimate the power of ascension corresponding to any given weight, *e. g.* 1000 pounds; since the levities are nearly as the cubes of the diameters, and consequently the diameters as the cube roots of the levities; and the levities being as 133 to 1000, *i. e.* nearly as 1 to 8, the cube-roots are as 1 to 2; consequently $1 : 2 :: 35 : 70$ feet, the diameter of a Montgolfier, made of the same thickness of stuff as the former, and capable of lifting 1000 pounds. Pursuing the same kind of calculation, it is easy to estimate the size of a balloon, made of stuff of a given thickness, and filled with air of a given density, that will just float in air. From the weight of a cubic foot of common air, subtract that of a cubic foot of the lighter or contained air; then divide 6 times the weight of a square foot of the stuff by the remainder, and the quotient will be the diameter, in feet, of the balloon that will just float at the surface of the earth. Suppose the stuff to be 1 pound to the square yard, or $\frac{16}{9}$ ounces to the square foot, and this multiplied by 6 gives $\frac{32}{3}$; then the cubic foot of common air weighing $1\frac{1}{5}$ ounce, and of heated air $\frac{2}{3}$ of the same, the difference being $\frac{2}{5}$;

consequently $\frac{32}{3}$ divided by $\frac{2}{5}$, gives $26\frac{2}{3}$ feet, which is the diameter of a Montgolfier that will just float: but if inflammable air, $\frac{1}{6}$ the weight of common air, be used, the difference between $1\frac{1}{5}$ and $\frac{1}{6}$ of it is one; by which dividing $\frac{32}{3}$ or $10\frac{2}{3}$, the quotient $10\frac{2}{3}$ feet will be the diameter of an inflammable air-balloon that will just float. If the diameter, in either of these cases be increased, the respective balloons will ascend in the atmosphere.

In order to determine the height to which a given balloon will rise, when the diameter of the balloon, and the weight that exactly balances it are given, proceed in the following manner:—compute the contents of the globe in cubic feet, and divide its restraining weight in ounces by this content, and the quotient will be the difference in density or specific gravity of the atmosphere at the surface of the earth, and that at the height to which the balloon will rise; subtract this difference or quotient from $1\frac{1}{5}$ or 1, 2, the density at the earth, and the remainder will be the density at that height; then the height corresponding to that density will be found with sufficient exactness in the annexed Table.

Height in miles.	Density.
0	1.200
$\frac{1}{4}$	1.141
$\frac{1}{2}$	1.085
$\frac{3}{4}$	1.031
1	0.980
$1\frac{1}{4}$	0.932
$1\frac{1}{2}$	0.886
$1\frac{3}{4}$	0.842
2	0.800
$2\frac{1}{4}$	0.761
$2\frac{1}{2}$	0.723
$2\frac{3}{4}$	0.687
3	0.653

e. g. Let the diameter of the balloon be 35 feet, its capacity 22458, and the levity of the first 976 pounds, or 15616 ounces; the quotient of the latter number divided by the former, *i. e.* $\frac{15616}{22458}$ is .695, which is the density at the utmost height, and to which in the Table corresponds somewhat less than $2\frac{1}{2}$ miles, and this is the height to which the balloon will ascend. When the same balloon was filled with heated air, its levity was equal to 133 pounds, or 2128 ounces, which divided by 22458, the capacity, gives the quotient, .095; and this subtracted from 1.200, leaves 1.105 for the density; to which, in the Table corresponds half a mile, or more nearly $\frac{3}{8}$ of a mile. Such are the heights to which these balloons would nearly ascend, if they retained their figure, and lost none of the contained air: or, more precisely, these are the heights at which they would settle; for their acquired velocity would at first carry them above these heights, till their motion would be destroyed; and then they would descend below these heights, though not so much as they had gone above them: after which they would reascend, and pass these heights again, but not so far as they had gone below them; thus vibrating alternately above and below these heights, but every time less and less. These calculations for finding the height to which the balloon will ascend, are formed independently of the different states of the thermometer at the highest point and at the surface of the earth; but the allowances to be made on this account will appear from what is delivered under the article ATMOSPHERE.

Next to the shape, it is necessary to consider the stuff that is most proper for forming the envelope of the inflammable or rarefied air. Silk stuff, especially that which is called lutestring, properly varnished, has been most commonly used for inflammable air-balloons: and common linen, lined within and without with paper, varnished, for those of rarefied air. Varnished paper, or gold beater's skin, will answer the purpose for making small inflammable air-balloons; and the small rarefied air-balloons may be made of paper without any varnish or other preparation.

The stuff for large balloons of both kinds require some previous preparation. The best mode of preparing the cloth for a machine upon Montgolfier's principle, is first to soak it in a solution of sal ammoniac and size, using one pound of each to every gallon of water; and when the cloth is quite dry, to paint it over with some earthy colour, and strong size or glue. It may be also varnished over, when perfectly dry, with some stiff oily varnish or simple drying linseed oil; which would dry before it penetrates quite through the cloth.

The varnish for the silk or linen of the inflammable air-balloons should be impermeable to the inflammable gas, pliable, and sufficiently dry to adhere firmly to the stuff. In France much has been said of the elastic gum varnish; but the composition of it is kept a secret. This gum is known to be soluble in divers essential oils, and also by vitriolic ether. The former solution forms a varnish which never perfectly dries: the latter dries readily, but the solution is too dear for common use. The following varnish has been recommended. To one pint of linseed oil, add two ounces of litharge, two ounces of white vitriol, and two ounces of gum sandarach; boil the whole for about an hour over a slow fire; then let it cool: separate it from the sediment, or strain it through a sieve, and dilute it with a sufficient quantity of spirits of turpentine. But the best varnish for an inflammable air-balloon is made with bird-lime. Mr. Cavallo directs to prepare it in the following manner, which, in his opinion, is preferable to that of M. Faujas de Saint Fond. In order to render linseed oil drying, boil it with two ounces of saccharum saturni and three ounces of litharge, for every pint of oil, till the oil hath dissolved them; then put a pound of bird-lime and half a pint of the drying oil into a pot of iron or copper, holding about a gallon; and let it boil gently over a slow charcoal fire till the bird-lime ceases to crackle; then pour upon it two pints and a half of drying oil, and boil it for about an hour longer, stirring it often with an iron or wooden spatula. As the varnish in boiling swells much, the pot should be removed from the fire and replaced when the varnish subsides. Whilst it is boiling, it should be occasionally examined, in order to determine whether it has boiled enough. For this purpose, take some of it upon the blade of a large knife, and after rubbing the blade of another knife upon it, separate the knives, and when on their separation the varnish begins to form threads between the two knives, it has boiled enough, and should be removed from the fire. When it is almost cold, add about an equal quantity of spirits of turpentine, mix both well together, and let the mass rest till the next day; then having warmed it a little, strain and bottle it. If it is too thick, add more spirits of turpentine. This varnish should be laid upon the stuff, when perfectly dry, in a luke-warm state; a thin coat of it upon one side, and about twelve hours after two other coats should be laid on, one on each side, and in twenty-four hours the silk may be used.

Mr. Blanchard's method of making elastic gum varnish for the silk of a balloon is as follows. Dissolve elastic gum, cut small, in five times its weight of spirits of turpentine, by keeping them some days together; then boil one ounce of this solution in eight ounces of drying linseed oil for a few minutes, and strain it. Use it warm.

The pieces of which an inflammable air-balloon is to be formed, must be cut of a proper size, according to the proposed dimensions of it, when the varnish is sufficiently dry. The pieces that compose the surface of the balloon are like

thofe gores that form the fuperficies of a globe: and the beft method of cutting them is to defcribe a pattern of wood or ftiff card-paper, and to cut the filk or ftuff upon it. One of thefe pieces, that may ferve as a pattern for others, is reprefented in *Plate* I. *Pneumatics, fig.* 2. In this figure, fuppofe A E and B C to be two right lines perpendicular to each other. Then find the circumference anfwering to the given diameter of the balloon in feet and decimals of a foot; and make A D and D E each equal to a quarter of the circumference, fo that A E may be equal to half the circumference. Divide A D into 18 equal parts, and to the points of divifion apply the lines *fg*, *hi*, *kl*, &c. parallel to each other, and perpendicular to A D. Divide the whole circumference into twice the given number of pieces, and make D C and D B each equal to the quotient of this divifion; fo that B C will be equal to the greateft breadth of one of thofe pieces. Multiply this quotient or D C by the decimals annexed to *fg*, viz. 0.99619, and the product expreffes the length of *fg*; and multiply D C by the decimals annexed to *hi*, and the product expreffes the length of *hi*, &c. Having thus found the lengths of all thefe lines, draw by hand a curve line, paffing through their extremities, and this will be the edge of one quarter of the pattern. The other quarters A B D, E B D, E D C, may be eafily defcribed by applying to each of them a piece of paper equal to A D C. Suppofe the diameter of the balloon to be 20 feet, and that it is to be made of 12 pieces. In order to draw the pattern, find the circumference of the balloon, which is 62.83 feet, and dividing it by 4, the quotient is 15.7 feet: confequently A D and D E will be each equal to 15.7 feet. Divide the circumference 62.83 by 24, or double the number of pieces that are to form the balloon; and the quotient 2.618 feet will be the length of D C or B D; therefore B C is equal to 5.236 feet. Then dividing A D into 18 equal parts, and drawing the parallel lines from the points of divifion, find the length of thefe lines by multiplying 2.618 by the decimals annexed to that line: thus, 2.618 multiplied by 0.99619 gives 2.608 feet for the length of *fg*; and multiplying 2.618 by 0.98481, we fhall have 2.578 feet for the length of *hi*, &c. The pieces cut after fuch a pattern fhould be left about one half or three quarters of an inch all round larger than the pattern, in order to allow for the feams. They may be joined by laying about half an inch of the edge of one piece over the edge of the other, and fewing them with a double ftitching. Mr. Blanchard joins them very expeditioufly in the following manner. He lays about half an inch of the edge of one piece flat over the edge of the other, and paffes a hot iron over it; in doing which, a piece of paper ought to be laid both under and over the filk. The joining may be rendered more fecure, by running it with a filk thread, and fticking a ribband over it. The ribbands laid over feams may be ftuck with common glue, provided the varnifh of the filk is properly dried. When the glue is quite dry, the ribbands fhould be varnifhed over, to prevent their being unglued by the rain.

To the upper part of the balloon there muft be adapted a valve, opening inward, to which is annexed a ftring paffing through a hole made in a fmall round piece of wood which is faftened to the loweft part of the balloon oppofite to the valve, to the boat below it; fo that the aeronaut may open it as occafion requires, and let the inflammable air out of the balloon. To the lower part of the balloon are fixed two pipes of the fame ftuff with the covering, fix inches in diameter for a balloon of thirty feet, and much larger for balloons of greater fize, and long enough to reach the boat. Thefe pipes are the apertures through which the inflammable air is introduced into the balloon.

The boat may be made of wicker-work, and covered with leather, well painted or varnifhed over. The beft method of fufpending it is by means of ropes, proceeding from the net which goes over the balloon. This net fhould be formed to the fhape of the balloon, and fall down to the middle of it, and have various cords proceeding from it to the circumference of a circle, about two feet below the balloon; and from that circle other ropes fhould go to the edge of the boat. This circle may be made of wood, or of feveral pieces of flender cane bound together. The mefhes of the net may be fmall at top, againft which part of the balloon the inflammable air exerts the greateft force, and increafe in fize as they recede from the top. A hoop has been fometimes put round the middle of the balloon for faftening the net. This is not abfolutely neceffary; but when ufed, it is beft made of pieces of cane bound together, and covered with leather. When the balloon and its appendages are conftructed, the next object of importance is to procure proper materials for filling it. With refpect to thofe inflated by heated air, nothing need be faid till the method of filling them is defcribed.

Inflammable air for balloons of the other kind may be obtained in feveral ways; but the beft methods are by applying acids to certain metals; by expofing animal, vegetable, and fome mineral fubftances, in a clofe veffel, to a ftrong fire; or by tranfmitting the vapour of certain fluids through red-hot tubes.

In the firft of thefe methods, iron, zinc, and vitriolic acid, are the materials moft commonly ufed. The vitriolic acid muft be diluted with five or fix parts of water. Iron may be expected to yield in the common way about 1700 times its own bulk of gas; or 4½ ounces of iron, the like weight of oil of vitriol, and 22½ ounces of water will produce one cubic foot of inflammable air: fix ounces of zinc, an equal weight of oil of vitriol, and 30 ounces of water, are neceffary for producing the fame quantity. It is more proper to ufe the turnings or chippings of great pieces of iron, as of cannon, &c. than the filings of that metal; becaufe the heat attending the effervefcence will be diminifhed, and the diluted acid will pafs more readily through the interftices of the turnings, when they are heaped together, than through the filings which ftick clofer to one another. The weight of the inflammable air, thus obtained by means of acid of vitriol, is, in the common way of procuring it, generally one-feventh part of the weight of common air; and with the neceffary precautions for philofophical experiments, lefs than one-tenth of the weight of common air. The other elaftic fluids, which are generated with the inflammable air, may be feparated from it by paffing the inflammable air through water, in which quick-lime has been diffolved; the water will abforb thefe fluids, cool the inflammable air, and prevent its overheating the balloon, when it is introduced into it. As white vitriol is fold much dearer than the vitriol of iron, it will be a faving to make the inflammable air by means of zinc and vitriolic acid, rather than of this acid and iron: becaufe the fale of the white vitriol arifing from the former will, in a degree, be a compenfation for the expence of the materials.

Inflammable air may alfo be obtained at a much cheaper rate by the action of fire on various fubftances; but the gas thus obtained is not fo light as that produced by the effervefcence of acids and metals. The fubftances proper to be ufed for this purpofe are pit-coal, afphaltum, amber, rock oil, and other minerals; wood, and efpecially oak, camphor oil, fpirits of wine, æther, and animal fubftances, which yield air of different degrees and of various fpecific gravity. But pit-coal is the fubftance moft proper to be ufed. A pound

of pit-coal, expofed to a red heat, yields about three cubic feet of inflammable air, which, whether it be paffed through water or not, weighs about one-fourth of the weight of an equal bulk of common air.

Dr. Prieftley obferves, that animal or vegetable fubftances will yield fix and even ten times more inflammable air, when the fire is fuddenly increafed than when it is gently raifed, though it be afterwards made very ftrong. And Mr. Cavallo informs us, that the various fubftances above enumerated generally yield all their inflammable air in about an hour's time. The ufual method is to inclofe the fubftances in earthen or iron veffels, and thus to expofe them to a ftrong fire fufficient to make the veffels red-hot; the inflammable air proceeding from the aperture of the veffel, is received into a tube or refrigeratory, and paffing through the tube or worm, is at laft collected in a balloon or other veffel. A gun-barrel has been often ufed for effays of this kind. The manner of conducting this procefs is particularly defcribed by Mr. Cavallo, *ubi infra.*

The laft method of obtaining inflammable air was lately difcovered by Mr. Lavoifier, and alfo by Dr. Prieftley. Mr. Lavoifier made the fteam of boiling water pafs through the barrel of a gun, kept red-hot by burning coals. Dr. Prieftley ufes, inftead of the gun-barrel, a tube of red-hot brafs, upon which the fteam of water has no effect, and which he fills with the pieces of iron which are feparated in the boring of cannon. By this method he obtains an inflammable air, the fpecific gravity of which is to that of common air as 1 to 13. In this method, a tube about three quarters of an inch in diameter, and about three feet long, is filled with iron turnings; then the neck of a retort or clofe boiler is luted to one of its ends, and the worm of a refrigeratory is adapted to its other extremity. The middle part of the tube is then furrounded with burning coals, fo as to keep about one foot in length of it red-hot, and a fire is always made under the retort or boiler fufficient to make the water boil with vehemence. In this procefs a confiderable quantity of inflammable air comes out of the worm of the refrigeratory. It is faid that iron yields one half more air by this means, than by the action of vitriolic acid. See Hydrogen.

Balloons of the fmaller fize, fuch as thofe of two or three feet in diameter, and alfo bladders, may be filled with inflammable air, after paffing it through water, by means of the following fimple apparatus. See *Plate* I. *Pneumatics, fig.* 3. A is the bottle that contains the ingredients which produce the gas: BCD is a tube in form of a fyphon, faftened by one extremity into the neck of this bottle, and paffing through a hole of the ftopper of another bottle E, it extends fo far as almoft to touch the bottom of this bottle, which is nearly full of water. To another hole made in the cork of the bottle E is adapted another tube, to the outward extremity of which a bladder, or the aperture of the balloon is tied. The inflammable air, coming out of the aperture D of the tube, paffes through the water of the bottle E, and then enters into the bladder or balloon. Two fmall cafks might be ufed inftead of the bottles A and E.

Another apparatus for producing hydrogen and conveying it into a balloon is exhibited in *fig.* 4. ABC is a veffel made of clay, or of iron, in the form of a Florence flafk; and the fubftance yielding gas is introduced into it fo as to occupy about 4ths, or lefs, of its cavity. If the fubftance fwell much by the action of the fire applied to it, a tube of brafs, or firft a brafs and then a leaden tube muft be luted to the neck C of the veffel, and the extremity D of the tube is made to pafs through the water of a tub H I, and to terminate under an inverted veffel E F, to the upper aperture of which the balloon, or a tube going to the balloon is adapted. When the part, A B, of the veffel is put into the fire, and made red-hot, the inflammable air that is generated will come out of the tube C D, and paffing through the water of the tub, it will at laft enter into the balloon G. As a confiderable quantity of common air remains in the inverted veffel E F, before the operation is begun, it fhould have a ftop-cock, K, through which it may be drawn out by fuction, and then the water will afcend as high as the ftop-cock. The aperture of the veffel, E F, fhould be at leaft one foot below the furface of the water in H I; and the fire fhould be at a fufficient diftance from the tub H I, that the inflammable air, if any of it fhould efcape, may not take fire and do injury.

The method of filling large aeroftatic machines with rarefied air is as follows. A fcaffold ABCD (*Plate* II. *fig.* 5.) the breadth of which is at leaft two-thirds of the diameter of the machine, is elevated about fix or eight feet above the ground. From the middle of it defcends a well E F, rifing about two or three feet above it, and reaching to the ground, furnifhed with a door or two, through which the fire in the well is fupplied with fuel. The well fhould be conftructed of brick or of plaftered wood; and its diameter fhould be fomewhat lefs than that of the machine. On each fide of the fcaffold are erected two mafts H I, K L, each of which has a pulley at the top, and rendered firm by means of ropes K G, K P, H P, H G. The machine to be filled is placed on the fcaffold, with its neck round the aperture of the well. The rope paffing over the pullies of the two mafts, ferves, by pulling its two ends, to lift the balloon about fifteen feet or more above the fcaffold: and the reft of the machine is reprefented by the dotted lines in the figure M N O. The machine is kept fteady and held down, whilft filling, by ropes paffing through loops or holes about its equator; and thefe ropes may be eafily difengaged from the machine, by flipping them through the loops, when it is able to fuftain itfelf. The proper combuftibles to be lighted in the well are thofe which burn quick and clear, rather than fuch as produce much fmoke; becaufe it is hot air, and not fmoke, that is required to be introduced into the machine. Small wood and ftraw have been found to be very fit for this purpofe. Mr. Cavallo obferves, as the refult of many experiments with fmall machines, that fpirits of wine are upon the whole the beft combuftible; but its price may prevent its being ufed for large machines. As the current of hot air afcends, the machine will foon dilate, and lift itfelf above the fcaffold and gallery, which was covered by it. The paffengers, fuel, inftruments, &c. are then placed in the gallery. When the machine makes efforts to afcend, its aperture muft be brought, by means of the ropes annexed to it, towards the fide of the well, a little above the fcaffold. The fire-place is then fufpended in it; the fire lighted in the grate; and the lateral ropes being flipped off, the machine is abandoned to the air. It will appear in the atmofphere as it is reprefented in *fig.* 6. It has been determined by accurate experiments, that only one-third of the common air can be expelled from thefe large machines; and therefore, the afcending power of the rarefied air in them can be eftimated as only equal to half an ounce avoirdupois for every cubic foot. The apparatus for filling an inflammable air balloon is reprefented in *fig.* 7. A, A are two tubs, about three feet in diameter, and nearly two feet deep, inverted in larger tubs, B, B, full of water. At the bottom of each of the inverted tubs there is a hole, to which is adapted a tin tube E, about feven inches in diameter, and feven or eight inches long. To thefe tubes the filken tubes of the

balloon are tied. Each of the tubs, B, is furrounded by feveral ftrong cafks, fo regulated in number and capacity, as to be lefs than half full, when the materials are equally diftributed. In the top of each of thefe cafks are two holes; and to one of the holes is adapted a tin tube, formed fo as to pafs over the edge of the tub B, and through the water, and to terminate with its aperture under the inverted tub A. The other hole, which ferves for fupplying the cafk with materials, is ftopped with a wooden plug. Thefe tin tubes may be about three inches and a half in diameter, and the other holes may be fmaller. Two mafts, with a rope, &c. are ufed for this machine, as well as for the former, although they are not abfolutely neceffary; becaufe the balloon, by means of a narrow fcaffold, or other contrivance, may be elevated five or fix feet above the level of the tubs A A. When the balloon is to be filled, the net is put over it and fufpended, as exhibited in CDF: and having expelled all the common air from it, its filk tubes are faftened round the tin tubes EE, and the materials in the cafks are properly proportioned; the iron being firft put in, then the water, and laftly the vitriolic acid. The balloon will foon be inflated by this inflammable air, and fupport itfelf without the aid of the rope GH. As the filling advances, the net is adjufted round it, the cords, proceeding from the net, are faftened to the hoop MN; the boat IK is fufpended from the hoop MN, and every thing neceffary for the voyage is depofited in the boat. When the balloon is a little more than three quarters full, the filken tubes are feparated from the tin tubes, and their extremities being tied, they are placed in the boat. Finally, when the aeronauts are feated in the boat, the lateral ropes are flipped off, and the machine afcends in the air, appearing as in *fig.* 8. In order to produce fuch a bulk of inflammable air as is neceffary for a balloon of 30 feet in diameter, whofe capacity is 14137 cubic feet, there will be required about 3900 pounds of iron turnings, 3900 pounds of vitriolic acid, and 19500 pounds of water. The balloon will not be above three quarters full.'

Thefe proportions, ftated by Mr. Cavallo, are too great with refpect to the metal and acid, and too fmall with regard to the water. Mr. Lunardi, who had confiderable experience in the practice of aeroftation, filled his balloons at Edinburgh and Glafgow, with about 2000 pounds of the chippings of cannon procured from Carron, the fame quantity of vitriolic acid, and 12,000 pounds of water. The iron was placed in layers in his veffels, with ftraw between them, in order to enlarge the furface expofed to the action of the acid. He ufed only two large cafks, which were funk in the ground, and conveyed the gas into the balloon without paffing through water; and he contrived to fill his balloon in lefs than half an hour, which operation had on former occafions required at leaft two hours.

The inflammable air with which they fill their balloons at the Aeroftatic Inftitute, not long fince eftablifhed in France, is obtained by the following method, which is fimple and not very expenfive. Six cylinders, or tubes of iron, are fixed by mafonry in a furnace of eafy and expeditious conftruction, in fuch a manner that the two ends of each cylinder project out of the furnace; and thefe are furnifhed with ftrong covers or lids of iron. Into thefe cylinders are introduced tubes of metal, one of which ferves to convey warm water into the red-hot cylinder, and the other to convey the air which is produced through a refervoir filled with cauftic ley, into the balloon. The cylinders are partly filled with the chippings or turnings of iron that are procured from the boring of cannon. The exceffive heat of the furnace, which is maintained by a fupply of charcoal during the operation, is communicated to the cylinders and their contents. In this ftate, boiling water is conveyed by one of the tubes to each cylinder; and as foon as it communicates with the inflamed iron, the water is decompofed: the one part, called the oxygen, attaches itfelf to the iron and calcines it; but the other part, or the hydrogen, is combined with a quantity of the igneous fubftance, called caloric, and becomes hydrogenous gas, or inflammable air, which remains in a permanent ftate of elaftic fluidity, and weighs feven or eight times lefs than the atmofpheric air. As the water contains a fmall quantity of carbon or fixed air, which would add weight to the air of the balloon, it is made to pafs through water in which cauftic alkali has been diffolved. This fluid attaches the carbon to itfelf, and thus the pure inflammable air is conveyed into the balloon. The cylinders in this operation, are fometimes fufed: for preventing which accident, a pyrometer is annexed to the extremity of the cylinder which projects from the furnace; and the fire is regulated by a fcale connected with the pyrometer. The operation of filling a balloon, 30 feet diameter, in this way will occupy about four hours.

In eftimating the afcending power of thefe machines, that of the inflammable air fhould be confidered as equal to one ounce avoirdupois for every cubic foot, which is one fixth of the weight of common air; and therefore, if the capacity of a balloon is 12000 cubic feet, and three-fourths of it are filled with inflammable air, obtained from iron and diluted vitriolic acid, the afcending power of that gas may be eftimated at 9000 ounces, or $562\frac{1}{2}$ pounds; from which the weight of the covering, boat, and other appendages, muft be fubtracted.

The conduct of balloons, when conftructed, filled, and actually afcending in the atmofphere, is an object of great importance in the practice of aeroftation. The method generally ufed for elevating or lowering the balloons with rarefied air, has been the increafe or diminution of the fire; and this is entirely at the command of the aeronaut, as long as he has any fuel in the gallery. The inflammable air-balloons have been generally raifed or lowered by diminifhing the weight in the boat, or by letting out fome of the gas through the valve. But the alternate efcape of the air in defcending, and difcharge of the ballaft for afcending, will by degrees render the machine incapable of floating; for in the air it is impoffible to fupply the lofs of ballaft, and very difficult to fupply that of inflammable air. Thefe balloons will alfo rife or fall by means of the rarefaction or condenfation of the inclofed air, occafioned by heat and cold. It has been propofed to aid a balloon in its alternate motion of afcent and defcent, by annexing to it a veffel of common air, which might be condenfed by lowering the machine, and rarefied again, by expelling part of it, for raifing the machine. But a veffel adapted to this purpofe muft be very ftrong, and, after all, the affiftance afforded by it would not be very confiderable. M. Meunier, in order to attain this end, propofes to inclofe one balloon filled with common air, in another filled with inflammable air: as the balloon afcends, the inflammable air is dilated, and of courfe compreffes the internal balloon containing common air; and by diminifhing its quantity, leffens its weight. If it fhould be neceffary to fupply this lofs, he fays it may be eafily done by a pair of bellows fixed in the gallery. Others have propofed to annex a fmall machine with rarefied air to an inflammable air-balloon by ropes, at fuch a diftance that the fire of the former might not affect the inflammable air of the latter: the whole apparatus, thus combined, of balloons formed on the two principles of heated and inflammable air,

might be raifed or lowered by merely increafing or diminifhing the fire in the lower balloon. Wings or oars feem to have contributed little to the effect of either raifing or lowering balloons.

Many fchemes have been propofed for directing the horizontal motion of balloons. Some have thought of annexing fails to a balloon, in order to give it the advantage of the wind; but to this propofal it has been objected, that as the aeroftatic machines are at reft with refpect to the air that furrounds them, they feel no wind, and confequently can derive no benefit from the fails. An ingenious writer obferves, that the cafe of veffels at fea is quite different from that of balloons; becaufe the former move with a velocity incomparably lefs than that of the wind impelling them, on account of the refiftance of the water; and therefore, the difference between the velocity of the wind, and that of fhips, occafions that ftream of air which acts upon the fails. But a balloon, finding no refiftance, acquires the fame velocity with the furrounding air, and therefore can feel no wind. The fame author adds, that the moft rational projects for directing an aeroftatic machine are thofe which propofe to exert a force againft the ambient air on one fide of the machine, fo as to move it in the oppofite direction. Oars and wings are the only inftruments that have been ufed for this purpofe with any meafure of fuccefs; but farther experiments are neceffary to afcertain their effect. If wings or oars be ufed, the beft method of moving them is by the immediate application of human power, as in the cafe of the oars of boats on the water. However they fhould be as large and light as poffible; and they may be made of filk ftretched between wires, tubes, or fticks. If they are flat they muft be turned edgeways when they are moved in the direction of the balloon's courfe, and flat in the oppofite direction. One of the wings, ufed by Mr. Blanchard, is reprefented in *fig.* 9. That ufed by Mr. Lunardi confifted of many filk fhutters or valves ABC D, DE C F, &c. (*fig.* 10.) each of which opens only on one fide, viz. A D B C upon the line A B, D E C F upon the line D C, &c; and by this conftruction, it becomes unneceffary to turn thefe oars edgeways. One of the wings, conftructed by Zambeccari is exhibited in *fig.* 11, and is nothing more than a piece of filk ftretched between two tin tubes fet at an angle; and fo contrived as to turn edgeways of themfelves, when they go in one direction. *Fig.* 12. reprefents one of the wings ufed by Meffrs. Roberts, in the voyage of September 19th, 1784. The greateft effect produced by the wings of an aeroftatic machine was that which occurred in this voyage. It is not difficult to determine what force is neceffary to move a given machine in the air with any propofed velocity. Dr. Hutton found, from accurate experiments, that a globe of $6\frac{1}{8}$ inches in diameter, and moving with a velocity of 20 feet in a fecond, fuftains a refiftance from the air, which is equal to the weight or preffure of one ounce avoirdupois; and that with different furfaces and the fame velocity, the refiftances are directly proportional to the furfaces nearly; and alfo that, with different velocities, the refiftances are proportional to the fquares of the velocities nearly. By thefe data the refiftance to move a given balloon with any velocity may be affigned. Let the balloon be 35 feet in diameter; then if it moved with the velocity of 20 feet per fecond, or almoft 14 miles per hour, it would counteract a refiftance equal to 271 pounds; with a motion of feven miles an hour, the refiftance would be 68 pounds; and at three miles and an half in an hour, the refiftance would be 17 pounds; and fuch is the force with which the aeronauts muft act on the air in a contrary direction, in order to communicate fuch a degree of motion to the machine. If the balloon move through a rarer part of the atmofphere than that at the furface of the earth, as $\frac{1}{3}$d or $\frac{1}{4}$th, &c. rarer, the refiftance will be lefs in the fame proportion; yet the force of the oars will be diminifhed as much; and therefore the fame difficulty remains. It may be obferved in general, that the aeronaut muft ftrike the air, by means of his oars, with a force juft equal to the refiftance of the air or the balloon, and therefore he muft ftrike that air with a velocity which muft be greater as the furface of the oar is lefs than the refifted furface of the globe, but not in the fame proportion, becaufe the force is as the fquare of the velocity. Suppofe that the aeronaut acts with an oar equal to 100 fquare feet of furface to move the balloon above-mentioned at the rate of 20 feet per fecond, or 14 miles an hour, then he muft move this oar with the great velocity of 62 feet per fecond, or nearly 43 miles an hour: and fo in proportion for other velocities of the balloon. Hence it is highly probable, that it will never be in the power of man to guide fuch machines with any tolerable degree of fuccefs, efpecially when any confiderable wind blows, which is generally the cafe. A helm feems to have no particular power in directing the courfe of a balloon, for the fame reafon that has been alledged to evince the inefficacy of fails. We have not in air, as in water, fays count de Mirabeau, in his Confiderations on the Order of Cincinnatus, the refource of a fixed point of action upon a fluid, which has alfo much greater refiftance than air. He adds, that as there are different currents of air, fometimes in oppofite directions, and balloons are capable of afcending and defcending in fearch of thefe currents, this circumftance may favour the hope of directing aeroftatic machines. Perhaps, an attention to the means by which birds fly againft the wind, added to obfervations of comparative anatomy upon fifhes and birds, which furmount the currents of the two fluids that are common to us and them, may alfo fuggeft new ideas with refpect to the direction of balloons. Time alone, and numerous experiments, can bring thefe reflections to maturity, and realize the expectations fuggefted by them.

Several of the foreign journals have lately announced an invention of profeffor Danzel for directing an air-balloon through the atmofphere. With this view he has conftructed two cylinders, or axles, to the ends of which are fixed, in the form of a crofs, four fails, or oars, moveable at the point of their infertion in the cylinder, in fuch a manner, that when made to move round by means of a handle, the eight oars, like the cogs of a water-mill wheel, prefent fucceffively to the air fometimes their flat fide and fometimes their edge. To caufe each oar to turn back on itfelf about the fourth part of a circle, M. Danzel has not only left fufficient play at the point where the ftick of each oar is inferted in the cylinder, but has placed the ftick in fuch a manner that the air itfelf makes the oar fall back, at each turn, with the neceffary velocity and precifion. Each of the two cylinders, armed with its four oars or fails, is deftined to occupy one fide of the balloon, with its four oars on each fide. For a farther account of this apparatus and of its effect, fee Philofophical Magazine, vol. iv. p. 108.

As parachutes, in the form of umbrellas, have been propofed in order to guard againft accidents, and to break the fall in cafes of fudden defcent, we fhall here annex a method of eftimating the power of fuch defenfive machines. A perfon, moving uniformly at the rate of ten feet per fecond, may defcend with fafety. For this uniform defcent the refiftance of the air muft be equal to the whole defcending weight. Suppofe then that the weight of the aeronaut is 150 pounds, and that the parachute is flat and circular, and

made of ſuch materials as that every ſquare foot of it weighs two ounces, and that the weight increaſes in the proportion of the increaſe of the ſurface; in this caſe the diameter of the parachute, which will deſcend at the rate of ten feet per ſecond, muſt be upwards of 78 feet; but if the parachute be concave on the lower ſide, its power will be rather greater, and its diameter may be leſs. In order to eſtimate the power of a flat circular parachute, or the reſiſtance it meets with from air of a mean denſity, when deſcending with a given velocity, ſay as the number 800 is to the ſquare of the velocity in feet, ſo is the ſquare of the diameter in feet to a fourth number, which will be the reſiſtance in pounds. And if it be required to know, with what velocity a parachute will deſcend with a given weight, ſay as the given diameter is to the ſquare root of the weight, ſo is the number 28¼ to a fourth, which will be the velocity in air of a mean denſity. Thus, if the diameter of a balloon be 50, and its weight, together with that of a man, be 530 pounds, the ſquare root of which is 23 very nearly; then 50 : 23 : : 28¼ : 13; and therefore the man and parachute will deſcend with the velocity of 13 feet per ſecond, which, as it is equal to that acquired by leaping freely from a height of two feet two inches, may be very ſafely ſuſtained.

Aerostation, *uſes of*. The advantages of an art, ſo lately diſcovered, have not yet been ſufficiently aſcertained; but we may reaſonably expect, conſidering the progreſs it has made in ſo ſhort a ſpace of time, that many benefits may reſult from the farther proſecution of it. To ſay the leaſt, it is unphiloſophical to diſcourage future trials and improvements, becauſe the uſes of this art do not immediately appear. With regard to philoſophical obſervations, derived from aeroſtation, it is acknowledged that very few have yet been made. The novelty of the diſcovery, and of the proſpect, ſays Mr. Cavallo, has generally diſtracted the attention; and beſides, moſt of the aerial voyages have been made by perſons who had pecuniary profit alone in view, or who were ſtimulated to aſcend in the atmoſphere for the ſake of the proſpect, or by the vanity of adding their names to the liſt of aerial adventurers. Aerial navigation, conſidered as a mode of travelling between diſtant places, independently of its furniſhing means of conveyance to places otherwiſe inacceſſible, is attended with many advantages and conveniences. The aeronaut has much leſs trouble with this machine than a ſailor with a ſhip in the moſt favourable circumſtances. With a moderate wind, aerial navigators have often gone at the rate of forty or fifty miles an hour, and very commonly at the rate of thirty miles without any agitation, or even feeling the wind, and without the danger of loſing time by being often becalmed. Aeroſtatic machines may ſerve the purpoſe of eſcaping from ſhips that cannot ſafely land, from beſieged places, and from other circumſtances of danger. A ſmall balloon ſix or ſeven feet in diameter, ſays an anonymous author in his propoſal of various means for ſaving the crews of veſſels ſhipwrecked near the coaſt, would anſwer this purpoſe, by carrying to the ſhore a ſtring capable of drawing a cord, with which ſeveral ropes might be afterwards conveyed to the veſſel. They alſo expedite the communication of important events by ſignals, and ſerve for exploring, from a great elevation, adjacent coaſts or regions, fleets and armies. To the latter of theſe purpoſes they have been actually applied by the French, in the courſe of the laſt war; and to the elevation of a balloon, and the information obtained in conſequence of thus reconnoitering the army of the enemy, they aſcribe the ſignal victory obtained in the battle of Fleurus in 1794. The balloon employed on this occaſion, was called the *Entreprenant*, and it was under the direction of M. Coutel, the captain of the aeronauts at Meudon, accompanied by an adjutant and a general. He aſcended twice in the ſame day, to the height of 220 fathoms, for the purpoſe of obſerving the poſition and manœuvres of the enemy. He continued each time four hours in the air, and correſponded with General Jourdan, who commanded the French army, by means of pre-concerted ſignals. The enterpriſe was diſcovered by the enemy, and a battery opened its fire againſt the aſcending aeronauts; but they ſoon gained an elevation which was beyond the reach of their fire. This balloon was prepared under the direction of the *Aeroſtatic* Institute, for the uſe of the army of the north; as were alſo another called *Celeſte*, for the army of the Sambre and Meuſe, and the *Hercule* and *Intrepide*, for the army of the Rhine and Moſelle. Another, thirty feet in circumference, and weighing 160 pounds, was deſtined for the army of Italy. A new machine, invented by M. Conte, the director of the Aeroſtatic Inſtitute, was deſigned to aid the aeronauts in communicating intelligence, and was denominated the *Aeroſtatic* Telegraph. Balloons may likewiſe ſerve to explore the ſtate of the atmoſphere at different heights, and to furniſh obſervations, which ſhall illuſtrate a variety of phenomena, depending on the denſity, temperature, and other qualities of the air. From one experiment that has been already made we learn, that the air of a high region, preſerved and examined by means of nitrous air, was found to be purer than the air below. The application of theſe machines to electrical experiments, is a very obvious uſe of which they are capable. The firſt perſon who employed them in this way ſeems to have been the Abbé Bertholon, at Montpellier. He raiſed ſeveral air balloons, furniſhed with long and ſlender wires, having their lower ends faſtened to a glaſs ſtick, or other inſulating ſubſtance; and thereby obtained from the wires electric fluid ſufficient to ſhew the attraction, repulſion, and even the ſparks of electricity. The exiſtence of a continual electricity, of the poſitive kind, in a clear atmoſphere, known indeed before, has been farther aſcertained by ſtrings faſtened to balloons floating in the atmoſphere. Some have apprehended danger from the electricity of the atmoſphere; and have thought that a ſtroke of lightning, or the ſmalleſt electrical ſpark, happening near a balloon, might ſet fire to the inflammable air, and deſtroy both the machine and the adventurers. Mr. Cavallo has ſuggeſted ſeveral conſiderations for diminiſhing apprehenſions of this kind. Balloons have been already raiſed in every ſeaſon of the year, and even when thunder has been heard, without injury. In caſe of danger the aeronauts may either deſcend to the earth, or aſcend above the region of the clouds and thunder ſtorms. Beſides, as balloons are formed of materials that are not conductors of electricity, they are not likely to receive ſtrokes, eſpecially as by being encompaſſed with air they ſtand inſulated. Moreover, inflammable air by itſelf, or unmixed with a certain quantity of common air, will not burn; ſo that if an electric ſpark ſhould happen to paſs through the balloon, it would not ſet fire to the inflammable air, unleſs a hole was made in the covering.

For a variety of other important and uſeful particulars relating to the ſubject of aeroſtation, we muſt refer to Mr. Cavallo's curious and compehenſive work, entitled, the Hiſtory and Practice of Aeroſtation, 8vo. 1785; which will afford the reader ample information concerning the principles of this art, and the hiſtory of its progreſs, the method of conſtructing and managing balloons, the nature and preparation of the materials of which they are formed, the obſervations and uſes to which they are

adapted, and rules for eſtimating the heights to which they aſcend.

See alſo for an account of ſeveral publications on this ſubject and abſtracts of their contents, Monthly Review, vol. lxix. p. 551.—vol. lxxi. p. 379.—vol. lxxiii. p. 99.—Meyer's Fragments ſur Paris, tom. ii. p. 107, &c. Hutton's Math. Dict. Art. Aeroſtation.

Air

AIR, in *Physics*, a thin, fluid, elastic, transparent, ponderous, compressible, and dilatable body; surrounding the terraqueous globe to a considerable height.

Air was considered by some of the ancients as an element; but then, by element, they understood a different thing from what we do. See ELEMENTS.

It is certain, that air, taken in the popular sense, is far from the simplicity of an elementary substance; though some of its properties and uses in a state of combination with various substances, from which it has been extricated by modern analysis, may entitle it to this appellation. Hence air may be distinguished into *proper* or *elementary*, and *vulgar* or *heterogeneous*.

AIR, *elementary*, or AIR *properly so called*, is a subtile, homogeneous, elastic fluid: the basis, or fundamental ingredient of the atmospherical air, and that which gives it the denomination.

In this sense, it likewise enters into the composition of most, or perhaps all bodies, existing in them under a solid form, deprived of its elasticity and most of its distinguishing properties, and serving as their cement, and the universal bond of nature; but capable, by certain processes, of being disengaged from them, recovering its elasticity, and resembling the air of our atmosphere. See Hale's Vegetable Statics, chap. vi. See GAS.

The peculiar nature of this aerial matter we know but little of; what authors have advanced concerning it being chiefly conjectural. We have no way of altogether separating it from the other matters with which in its purest state it is more or less combined, and consequently no way of ascertaining, with satisfactory evidence, its peculiar properties, abstractedly from those of other bodies.

Dr. Hook, and some others, maintain, that it is the same

ſame with their *ether*, or that ſine, fluid, active matter, diffuſed through the whole expanſe of the celeſtial regions; which coincides with Sir I. Newton's *ſubtile medium*, or ſpirit. In this view it is ſuppoſed to be a body *ſui generis*, ingenerable, incorruptible, immutable, preſent in all places, and in all bodies.

Others, conſidering only its property of elaſticity, which they account its eſſential and conſtituent character, ſuppoſe it to be mechanically producible; and to be no other than the matter of other bodies, ſo modified and altered, as to become permanently elaſtic. Sir Iſaac Newton obſerves, that the particles of denſe, compact, and fixed ſubſtances, cohering by a ſtrong attractive force, are not ſeparable without a vehement heat, or perhaps not without fermentation; and ſuch bodies being at length rarefied by ſuch heat or fermentation, become true *permanent air;* and diſtinguiſhable from vapour, which is only *apparent*, or *tranſient air*, as is evident from the experiment with the æolipile. Optics, Qu. 31, p. 371, 372. ed. 3. See Air, *atmoſpherical*.

Air, *vulgar* or *heterogeneous*, is a coalition of corpuſcles of various kinds, conſtituting together one fluid maſs, in which we live and move, and which we are continually receiving and expelling by reſpiration. The whole aſſemblage of this makes what we call the atmoſphere; where this air, or atmoſphere, terminates, there *ether* is ſuppoſed to commence; which is diſtinguiſhed from air by its not making any ſenſible refraction of the rays of light, as air does.

Air, in this popular and extenſive meaning of the term, is acknowledged by Mr. Boyle to be the moſt heterogeneous body in the univerſe. Boerhaave ſhews it to be an univerſal chaos, or colluvies, of all kinds of created bodies. Beſides the matter of light or fire, which continually flows into it from the heavenly bodies, and probably the magnetic effluvia of the earth; whatever fire can volatilize is found in the air.

Hence, for inſtance, 1. The whole foſſile kingdom muſt neceſſarily be found in it; for all of that tribe, as ſalts, ſulphurs, ſtones, metals, &c. are convertible into fume, and thus capable of being rendered part of the air. Gold itſelf, the moſt fixed of all natural bodies, is found to adhere cloſe to the ſulphur in mines; and thus to be raiſed along with it. Mr. Boyle obſerves, that beſide the ſaline effluvia of the common ſort, ſuch as the nitrous, vitriolic, marine, &c. there may be many compounded kinds of ſalts in the air, which we have not on earth, ariſing from different ſaline ſpirits, fortuitouſly meeting and mixing together. Thus, the glaſs windows of ancient buildings are ſometimes obſerved to be corroded, as if they had been worm-eaten; though none of the ſimple ſalts above-mentioned have the faculty of corroding glaſs.

Sulphurs too muſt make a conſiderable ingredient of the air, on account of thoſe many volcanos, grottos, caverns, and other ſpiracles chiefly affording that mineral, diſperſed through the globe.

2. All the parts of the animal kingdom muſt alſo be in the air: for beſides the copious effluvia continually emitted from their bodies, by the vital heat, in the ordinary proceſs of perſpiration; by means of which an animal, in the courſe of its duration, impregnates the air with many times the quantity of its own body; we find that any animal when dead, being expoſed to the air, is in a certain time wholly incorporated with it.

3. As to vegetables, none of that claſs can be ſuppoſed wanting; ſince we know that all vegetables, by putrefaction, become volatile.

The aſſociations, ſeparations, attritions, diſſolutions, and other operations of one ſort of matter upon another, may likewiſe be conſidered as ſources of numerous other neutral, or anonymous bodies, unknown to us.

4. Water is alſo diffuſed through the air in great abundance. Many familiar inſtances might be alledged to this purpoſe. A bottle of wine, when taken out of the cellar in the drieſt and hotteſt day of ſummer, will ſoon be covered with a denſe vapour, which is water depoſited by the air. The ſame appearance is obſerved on the outſide of any metallic veſſel, which, in warm weather, contains water cooled by ice or the ſolution of ſalt, or even ſpring water, which is ſome degrees colder than the air. For other facts of ſimilar kind, ſee Water.

Air, in this general ſenſe, is one of the moſt conſiderable and univerſal agents in all nature; being concerned in the preſervation of life, and the production of moſt of the phenomena relating to our world. Its properties and effects, including a great part of the reſearches and diſcoveries of the modern philoſophers, have in a conſiderable degree been reduced to preciſe laws and demonſtrations, in which form they make a very extenſive and important branch of the mixed mathematics, called Pneumatics.

Air, *mechanical properties and effects of*. The moſt conſiderable of theſe are its *fluidity*, *weight*, and *elaſticity*.

I. *Fluidity*. That the air is a fluid, is evident from the eaſy paſſage it affords to bodies through it; as in the propagation of ſmells, and other effluvia, and the eaſy conveyance it affords to ſounds: for theſe and ſimilar effects prove it to be a body, whoſe parts give way to any force impreſſed, and, in yielding, are eaſily moved among themſelves; which is the definition of a fluid. Beſides, it is certain, that no condenſation by preſſure, nor any degree of cold that has ever yet been produced, natural or artificial, have been ſufficient to deprive it of its fluidity. It is true, indeed, that real permanent air may be extracted from ſolid bodies, and may be alſo abſorbed by them; and in this ſtate it muſt be very much condenſed: but under what form it exiſts in thoſe bodies, or how its particles are combined together, the reſearches of philoſophy and chemiſtry have not yet been able to explore.

They who, with the Carteſians, make fluidity to conſiſt in a perpetual inteſtine motion of the parts, find that air anſwers alſo to that character: thus, in a darkened room, where the ſpecies of external objects are brought in by a ſingle ray, they appear in a continual fluctuation; and thus even the more accurate thermometers are obſerved never to remain a moment at reſt.

The cauſe of this fluidity of air is attributed by ſome later philoſophers to the fire intermixed with it; without which, they imagine, the atmoſphere would harden into a ſolid impenetrable maſs. And hence, the greater the degree of fire, the more fluid, moveable, and pervious is the air: and thus, as the degree of fire is continually varying, according to the circumſtances and poſition of the heavenly bodies, the air is kept in a continual reciprocation. See Buffon's Hiſt. Nat. Supp. vol. i. Hence, in a great meaſure, it is ſaid, that on the tops of the higher mountains, the ſenſes of ſmelling, hearing, &c. are found very feeble. The increaſed rarity of the air at a conſiderable height may account for this effect; but the above hypotheſis is contradicted by the more ſenſible experience of cold: the air, near the ſurface of the earth, deriving greater heat from the reflected than from the direct rays of the ſun.

II. *Weight* or *gravity*. Of this property of air the ancients were not altogether unapprised; though their sentiments on the subject were confused and unsatisfactory. Aristotle (de Cælo, lib. iv. c. 1. op. tom. i. p. 485.) observes, that all the elements, fire excepted, have weight; and he adds, that a bladder inflated with air, weighs more than when it is quite empty. Plutarch (de Placitis. lib. i. c. 12. tom. ii. p. 883.) and Stobæus (Eclog. Phys. lib. i. c. 17. p. 32. Ed. 1609.) quote Aristotle as teaching, that the weight of air is between that of fire and earth; and he himself, treating of respiration, (cap. vii. oper. tom. i. p. 722.) reports the opinion of Empedocles, who ascribes the cause of it to the weight of the air, which by its pressure insinuates itself with force into the lungs. Plutarch (de Placit. lib. iv. c. xxii. tom. ii. p. 903.) expresses, in similar terms, the opinion of Asclepiades on this subject; and represents him as saying, that the external air, by its weight, opened its way with force into the breast. Heron of Alexandria, in his treatise intitled *Spiritalia*, constantly applies the *elasticity* of the air to produce such effects as are sufficient to convince us that he well understood that property of it: and Ctesibius, admitting the principle of the air's elasticity, invented wind-guns, which have been considered as a modern contrivance. Philo of Byzantium (in Veter. Mathem. p. 77. Ed. Paris.) describes these curious machines, constructed upon the principle of the air's being capable of condensation. Seneca also (Quæst. Nat. lib. v. c. v. and vi.) was acquainted with the weight and elastic force of the air; for he describes the constant effort by which it expands itself when it is compressed, and affirms, that it has the property of condensing itself, and forcing its way through all obstacles that oppose its passage. See Dutens's Inquiry into the origin of the Discoveries attributed to the Moderns, p. 186. 1769. The followers of Aristotle, however, abandoned the sentiments of their master on this subject; and for many ages maintained a contrary doctrine. The effects which are now known to result from the weight and elasticity of the air, were for a long time attributed to the imaginary principle, called *fuga vacui*, or nature's abhorrence of a vacuum; and Galileo himself admitted the principle, though he assigned a limit to it, corresponding to the weight of a column of water 34 feet high. This distinguished philosopher, however, was well apprised of the weight of the air as a body; and, in his Dialogues, he points out two methods of demonstrating it, by weighing it in bottles. But the pressure of the air was discovered by his disciple, Torricelli. In the year 1643, it occurred to him, that whatever might be the cause by which a column of water, 34 feet high, is sustained above its level, the same force would sustain a column of any other fluid, which weighed as much as that column of water, on the same base; and hence he concluded, that quicksilver, being about 14 times as heavy as water, would not be sustained at a greater height than that of 29 or 30 inches. He then made the experiment, called after his name; and inferred from it, that the weight of the air incumbent on the surface of the external quicksilver, counterbalanced the fluid contained in the tube. By this experiment he not only proved, as Galileo had before done, that the air had weight, but that its weight was the cause of the suspension of water and quicksilver in pumps and tubes, and that the weight of the whole column of it was equal to that of a like column of quicksilver, 30 inches high, or of water 34 or 35 feet high; but he did not ascertain the weight of any particular quantity of it, as a gallon, or a cubic foot; nor its specific gravity to water, which had been done, though inaccurately, by Galileo. Torricelli's experiment was published at Warsaw, in Poland, by Valerianus Magnus, as his own discovery; but from the letters of Roberval, it appears, that Torricelli's claim to priority is indisputable; and that neither Valerianus, nor Honoratus Fabri, to whom it has been ascribed so early as the year 1641, can justly dispute it with him. The first discovery of the weight and elasticity of the air has been lately ascribed to Jean Rey, who wrote in 1629, before Galileo, Torricelli, Des Cartes, and Paschal. His fourth and tenth essays have been cited in favour of his claims; but though he was apprized that compression augmented the weight of the air, and he seems to have believed, with Aristotle and others at a very ancient period, that air was heavy, yet the proofs which he alleges were not sufficient to convince the incredulity of the peripatetics. The Torricellian experiment, by which the fact was established, and which father Mersenne received an account of in 1644, was immediately communicated to the philosophers of France, and repeated in various ways by Messrs. Paschal and Petit: and this gave occasion to the ingenious treatise published by Paschal, at 23 years of age, intitled, "Experiences Nouvelles touchant la Vuide." Having, after some hesitation, adopted Torricelli's idea, and abandoned the principle of a *fuga vacui*, he devised several experiments for confirming it. One of these was to make a vacuum above the reservoir of quicksilver, in which case he found that it sunk to the common level: and he then engaged M. Perrier, his brother-in-law, to execute the famous experiment of Puy-de-Domme, who found that the height of the quicksilver half way up the mountain was less by some inches than at the foot of it; and that it was still less at the top. These facts incontestibly proved, that it was the weight of the atmosphere which counterpoised the quicksilver. Des Cartes had also just notions of the power of the air for sustaining fluids above their level, as appears by some letters about this time, and some years before; and in one of these he lays claim to the idea of the Puy-de-Domme experiment. See Cartesii Opera. tom. ii. p. 243, 246.

The experiment of Paschal was repeated in various parts of the world; and particularly in 1653, by Dr. Power, in England; and in 1661, by Mr. Sinclair, professor of philosophy at Glasgow, in Scotland.

That the air is heavy, follows from its being a body; weight being an essential property of matter. And that it is a body, is evident from its excluding all other bodies out of the space it possesses; for if a glass jar be inverted into a vessel of water, the air, of which it is full, will allow but little water to enter into it. But we have many arguments to the same purpose from sense and experiment: thus, the hand, applied on the orifice of a vessel empty of air, soon feels the load of the incumbent atmosphere. Thus, glass vessels, exhausted of their air, are easily crushed to pieces by the weight of the air without. So, two small hollow segments of a sphere, four inches in diameter, exactly fitting each other, being emptied of air, are pressed together with a force equal to 188 pounds, by the weight of the ambient air; and that they are kept together by the pressure of the air is evident, by suspending them in an exhausted receiver, where they will separate of themselves. Farther, if a tube, close at one end, be filled with mercury, and the other end immerged in a bason of the same fluid, and thus erected, the mercury in the tube will be suspended at the height of about 30 inches above the surface of that in the bason. The reason of which suspension is, that the mercury in the tube cannot fall lower without raising that in the bason; which being pressed down by the weight of the incumbent atmosphere cannot give way, unless the weight of the mercury in the tube exceeds that of the air out of

it. That this is the cafe, is evident; becaufe, if the whole apparatus be included in the receiver of an air pump, the mercury will fall in proportion as the air is exhaufted; and on gradually letting in the air again, the mercury re-afcends to its former height. This makes what is ufually called the TORRICELLIAN *experiment*.

To fay no more, we can actually weigh air; for a veffel, full even of common air, is found, by a very nice balance, to weigh more than when the air is exhaufted; a quart of air weighing about 17 grains; and the effect is proportionably more fenfible, if the fame veffel be weighed full of condenfed air, and more efpecially in a receiver void of air.

The weight of air is continually varying, according to the different degree of heat and cold, and the concurrence of other caufes. Pafchal obferved it in France; and Des Cartes in Sweden, in 1650. Mr. Boyle, and others, obferved it in England, in 1656. Some obfervers noticed, that it was generally greateft in the night and in winter; and that its variations were moft confiderable during winter, and in the northern regions. Hence arofe the application of the BAROMETER to the ufes of a WEATHER-GLASS. Ricciolus eftimates the weight of air to that of water, to be as 1 to 1000; Merfennus as 1 to 1300, or 1 to 1356; Lana, as 1 to 640; Galileo only makes it as 1 to 400. Mr. Boyle, by a more accurate experiment, found it about London, as 1 to 938; and thinks, all things confidered, the proportion of 1 to 1000 may be taken as a medium; for there is no fixing any precife ratio, fince not only the air, but the water itfelf, is continually varying. Befides, experiments made in different places neceffarily vary, on account of the different heights of the places, the feafons of making the experiment, and the different denfities of air correfponding to thefe circumftances. It muft be added, however, that by experiments made fince, before the Royal Society, the proportion of air to water was, firft, found as 1 to 840; then, as 1 to 852; and a third time, as 1 to 860. Phil. Tranf. N° 181. And laftly, by a very fimple and accurate experiment of Mr. Hauksbee, the proportion was fettled, as 1 to 885. Phyf. Mechan. Exper. But thefe experiments being all made in the fummer months, when the barometer was 29¾ inches high, Dr. Jurin thinks, that at a medium between heat and cold, when the barometer is 30 inches high, the proportion between the two fluids may be taken as 1 to 800; which agrees with the obfervation of the honourable Mr. Cavendifh, the thermometer being at 50°, and the barometer at 29¾ inches. Phil. Tranf. vol. lvi. p. 152.

Sir George Shuckburgh, (Phil. Tranf. vol. lxvii. p. 560.) by a very accurate experiment, found it as 1 to 836; the barometer being at 29,27 inches, and the thermometer at 53°; and the comparative gravity of quickfilver to air, as 11364,6 to 1. The medium of all thefe is about one to 832 or 833, when reduced to the preffure of 30 inches of the barometer, and the mean temperature 55° of the thermometer. Upon the whole, it may be concluded, that when the barometer is at 30 inches, and the thermometer at the mean temperature of 55°, the denfity or gravity of water is to that of air as 833⅓ to 1; that is, as $\frac{2500}{3}$ to 1, or as 2500 to 3; and for any changes in the height of the barometer, the ratio varies proportionally; and alfo that the denfity of the air is altered by the $\frac{1}{440}$th part, for every degree of the thermometer above or below temperate. This number, which is a very good medium, having the fraction ⅓, gives exactly 1⅕th of an ounce for the mean weight of a cubic foot of air; the weight of the cubic foot of water being juft 1000 ounces avoirdupois, and that of quickfilver eqnal to 13600 ounces.

Air, then, being heavy and fluid, the laws of its gravitation, or preffure, may be inferred to be the fame as thofe of other fluids; and confequently its preffure muft be proportional to its perpendicular altitude. This is alfo confirmed by experiment. For removing the Torricellian tube to a more elevated place, where the incumbent column of air is fhorter, a proportionably fhorter column of mercury is fuftained; and that nearly at the rate of 100 feet for $\frac{1}{10}$th of an inch of quickfilver. On this principle depend the ftructure and office of the BAROMETER.

From hence, alfo, it follows, that the air, like all other fluids, muft prefs equally every way. This is confirmed by obferving, that foft bodies fuftain this preffure without any change of figure, and brittle bodies without breaking; though the preffure upon them be equal to that of a column of mercury thirty inches high, or a column of water of thirty-two or fomewhat more feet. It is obvious, that no other caufe can preferve fuch bodies unchanged, but the equable preffure on all fides, which refifts as much as it is refifted. And hence, upon removing or diminifhing the preffure on one fide only, the effect of the preffure is foon perceived on the other. For the quantity and effect of this preffure of the atmofphere on the human body, and on the furface of the earth, and the laws of different heights, fee ATMOSPHERE.

From the *gravity* of the air, confidered in connection with its *fluidity*, feveral of its ufes and effects may be eafily deduced.

1. By means of its weight, &c. it clofely invefts the earth, with all the bodies upon it; and conftringes and binds them down with a force amounting, according to the computation of M. Pafchal, to 2232 pounds weight upon every fquare foot, or upwards of 15 pounds upon every fquare inch. Hence it prevents, *e. gr.* the arterial veffels of plants and animals from being too much diftended by the impetus of the circulating juices, or by the elaftic force of the air, fo plentifully contained in the blood.—Thus we fee, in the operation of cupping, that, upon a diminution of the preffure of the air, the parts of the body grow tumid; which neceffarily alters the manner of the circulation through the capillaries, &c.

The fame caufe hinder the juices from oufing and efcaping through the pores of their containing veffels: this is experienced by fuch as travel up high mountains, who, in proportion as they afcend, find themfelves more and more relaxed; and at length become fubject to a fpitting of blood, and other hæmorrhages; becaufe the air doth not fufficiently conftringe the veffels of the lungs. Similar effects are obferved in animals that are enclofed under the receiver of the air-pump, who, as the air is taken from them, pant, fwell, vomit, and difcharge their urine and excrements. See VACUUM.

2. The weight of the air promotes the mixture of contiguous fluid bodies. Hence many liquids, as oils and falts, which readily and fpontaneoufly mix in air, remain, on the removal of it, in a ftate of feparation.

3. This gravity of air does in fome cafes determine the action of one body above another.

4. To the fame principle are chiefly owing our winds, which are only air put in motion by fome alteration in its equilibrium. It is the weight of the air that caufes the clouds and vapours to float in it.

III. *Elafticity*—or a power of yielding to an impreffion by contracting its dimenfions; and upon removing or diminifhing the impreffive caufe, of returning to its former fpace or figure, is another quality of air. This elaftic

force has been long accounted the diſtinguiſhing property of air; the other properties hitherto enumerated being common to it with other fluids; though, from late experiments, it appears more than probable, that the capacity of being compreſſed and expanded is not peculiar to air. See WATER and COMPRESSION.

This property of air has been long known, and was aſcertained by ſome experiments of lord Bacon, who, upon this principle, conſtructed his *vitrum calendare*, the firſt thermometer. Bacon. Nov. Organ. lib. ii. aph. 13.

Of this power we have numerous proofs.—Thus, a blown bladder being ſqueezed in the hand, we find the included air ſenſibly reſiſt; ſo that, upon ceaſing to compreſs, the cavities or impreſſions, made in its ſurface, are readily expanded again, and filled up.

On this property of elaſticity, the ſtructure and office of the AIR-PUMP depend.

Every particle of air always exerts this niſus, or endeavour to expand, and thus ſtrives againſt an equal endeavour of the ambient particles, whoſe reſiſtance happening by any means to be weakened, it immediately diffuſes itſelf into an immenſe extent. Hence it is, that thin glaſs bubbles, or bladders filled with air, and exactly cloſed, being included in the exhauſted receiver of an air-pump, burſt by the force of the included air. So a bladder quite flaccid, containing only the ſmalleſt quantity of air, ſwells in the receiver, and appears quite full. The ſame effect is alſo found by carrying the flaccid bladder to the top of a high mountain. This experiment ſhews, that the elaſticity of air is different from that of ſolid bodies: after theſe have been compreſſed, they only reſume the figure which they had loſt; whereas air, when the compreſſing force is removed, not only dilates, but occupies a much greater ſpace than it did before; nor is it eaſy to aſſign the limits of its expanſion. From ſome experiments of Col. Roy (Phil. Tranſ. vol. 67. p. 708.) it would ſeem, that the particles of air may be ſo far removed from one another, by the diminution of preſſure, as to loſe a very great part of their elaſtic force. It alſo appears that the elaſtic force of common air is greater than when its denſity is conſiderably augmented or diminiſhed by an addition to, or ſubtraction from, the weight with which it is uſually loaded; a fact which contradicts the experience of Boyle, Mariotte, and others. Theſe experiments alſo ſhew, that the elaſtic force of moiſt air is greatly ſuperior to that of dry air; in ſome caſes the total expanſion of the former was more than four times that of the latter.

It has been queſtioned among philoſophers, whether this elaſtic power of the air is capable of being deſtroyed or diminiſhed. Mr. Boyle made ſeveral experiments, with a view to diſcover how long air, brought to the greateſt degree of expanſion to which he could reduce it in his air-pump, would retain its ſpring; and could never obſerve any ſenſible diminution. Deſaguliers found that air, after having been encloſed for half a year in a wind gun, had loſt none of its elaſticity; and Roberval, after preſerving it in the ſame manner for ſixteen years, obſerved, that its expanſive projectile force was the ſame as if it had been recently condenſed. Nevertheleſs, Mr. Haukſbee concludes, from a later experiment, that the ſpring of the air may be ſo diſturbed by a violent preſſure, as to require ſome time to return to its natural tone. Dr. Hales inferred, from a number of experiments, that the elaſticity of the air is capable of being impaired and diminiſhed by a variety of cauſes, and of being actually deſtroyed, ſo that it is reduced to a fixed ſtate. Hence he alſo concludes, that elaſticity is not an eſſential immutable property of the particles of air; and that the atmoſphere is a chaos, conſiſting not only of elaſtic, but alſo of unelaſtic air-particles, which copiouſly float in it. Statical Eſſays, vol. i. p. 316.

The weight or preſſure of the air, it is obvious, has no dependence on its elaſticity; but would be the ſame, whether the air has ſuch a property or not. But the air, being elaſtic, is neceſſarily affected by the preſſure, which reduces it into ſuch a ſpace, as that the elaſticity which re-acts againſt the compreſſing weight, is equal to that weight. Indeed, the law of this elaſticity is, that it increaſes as the denſity of the air increaſes; and the denſity increaſes as the force increaſes by which it is preſſed. Now, there muſt neceſſarily be a balance between the action and re-action; *i. e.* the gravity of the air, which tends to compreſs it, and the elaſticity of the air, which endeavours to expand it, muſt be equal. And the elaſticity of the air not very different from its natural ſtate, being as the denſity, will of courſe be inverſely as the ſpace which it occupies.

Hence the elaſticity increaſing, or diminiſhing, univerſally, as the denſity increaſes or diminiſhes, *i. e.* as the diſtance between the particles diminiſhes, or increaſes, it is no matter whether the air be compreſſed and retained in ſuch ſpace, by the weight of the atmoſphere, or by any other means; it muſt endeavour, in either caſe, to expand with the ſame force. And hence if air near the earth be pent up in a veſſel, ſo as to cut off all communication with the external air, the preſſure of the incloſed air will be equal to the weight of the atmoſphere. Accordingly, we find mercury ſuſtained to the ſame height, by the elaſtic force of air incloſed in a glaſs veſſel, as by the whole atmoſpherical preſſure.

On the ſame principle air may be artificially condenſed; and hence the ſtructure of the AIR-*gun*.

Although it may be admitted as a general principle, that the denſity of the air is proportional to the force by which it is compreſſed, as the experiments of Mr. Boyle and Mr. Mariotte have evinced; yet in the caſe of condenſed air, the rule will not be ſtrictly applicable. When air is very forcibly compreſſed, ſo as to be reduced to ¼th of its ordinary bulk, it makes a greater reſiſtance, and requires a ſtronger force to compreſs it than the above principle allows. Hence it appears probable, that the particles of air cannot, by any poſſible preſſure, be brought into perfect contact, or form a ſolid maſs; and therefore that the degree of condenſation has its limit. Thus alſo in very high degrees of rarefaction, the elaſticity is decreaſed rather more than in an exact proportion to the weight or denſity of the air; whence it may be concluded, that there is a limit to its rarefaction or expanſion, ſo that it cannot be expanded to infinity. Nevertheleſs, the utmoſt limits to which air of the denſity which it poſſeſſes at the ſurface of the earth, is capable of being compreſſed, have not been aſcertained. Mr. Boyle reduced it at one time to the 14th part, and at another to the 40th part of its natural ſpace. (Works, vol. iii. p. 507.) Dr. Halley ſays, that he has ſeen it compreſſed ſo as to be 60 times denſer than in its natural ſtate, which is farther confirmed by Mr. Papin, and M. Huygens. Dr. Hales (Stat. Exp. vol. ii. p. 343, &c.) by means of a preſs, condenſed it 38 times; and by freezing water in an iron ball, or globe, into 1522 times leſs ſpace than it naturally occupies: in which ſtate its denſity or ſpecific gravity muſt be nearly double that of water; and as water is very ſlightly compreſſible, the particles of air muſt be in their nature different from thoſe of water; ſince it would otherwiſe be impoſſible to reduce air to a bulk 800 times leſs than that which it occupies in its natural ſtate.

However, Dr. Halley has aſſerted, in the Philoſophical Tranſactions, (Abr. vol. ii. p. 17.) that from the experi-

ments made at London, and by the Academy del Cimento at Florence, it might be safely concluded, that no force whatever is able to reduce air into 800 times lefs fpace than that which it naturally poffeffes on the furface of our earth. In anfwer to which, M. Amontons, in the Memoirs of the French Academy, maintains, that there is no affixing any bounds to its condenfation; that greater and greater weights will ftill reduce it into lefs and lefs compafs; that it is only elaftic in virtue of the fire which it contains; and that as it is impoffible ever abfolutely to drive all the fire out of it, it is impoffible ever to make the utmoft condenfation.

The elafticity of the air exerts its force equally in all directions; and when releafed from the force that compreffes it, it affumes a fpherical figure in the interftices of the bodies that contain it. By exhaufting the air from liquors placed under the receiver of an air-pump, the bubbles that gradually arife and are enlarged in fize, retain their round figure. Such are alfo the bubbles that difcharge themfelves from a plate of metal immerged in a fluid in the fame circumftances. On this account large glafs globes are always formed of a fpherical fhape by blowing air through an iron tube into a piece of melted glafs at the end of the tube.

The dilatation of the air by virtue of its elaftic force, is found to be very furprifing; and yet Dr. Wallis fuggefts, that we are far from knowing the utmoft of which it is capable. In feveral experiments made by Mr. Boyle, it dilated firft into 9 times its former fpace; then into 31 times; then into 60; and then into 150. Afterwards, it was brought to dilate into 8000 times its firft fpace: then into 10,000, and even at laft into 13,679 times its fpace; and this altogether by its own expanfive force, without the help of fire. Boyle's Works by Birch, vol. i. p. 21, 22. vol iii. p. 498, 499.

On this depend the ftructure and ufe of the MANOMETER. Hence it appears, that the air we breathe near the furface of the earth is compreffed by the weight of the fuperincumbent column into at leaft the 13679th part of the fpace it would poffefs *in vacuo*. But if the fame air be condenfed by art, the fpace it will take up when moft dilated, to that it poffeffes when condenfed, will be, according to the fame author's experiments, as 550,000 to 1.

We hence fee how wild and erroneous the obfervation of Ariftotle was, that air, rendered ten times rarer than before, changes its nature, and becomes fire.

It has generally been fuppofed, that air expands $\frac{1}{500}$ with each degree of the thermometer, commencing from the mean temperature 55°; and upon this principle tables have been computed by aftronomers for correcting their mean refractions; but Sir George Shuckburgh allows at this temperature an expanfion of $\frac{1}{435}$ for 1°. Phil. Tranf. v. 67. p. 564. Mr. Haukfbee obferved, that a portion of air, included in a glafs tube, when the temperature was at the freezing point, formed a volume which was to that of the fame quantity of air in the greateft heat of fummer in England as 6 to 7. Moift air has been expanded into more than 12 times the fpace occupied by it in its freezing ftate; and Merfennus by means of the æolipile expanded it into more than 70 times its natural bulk. Mufchenb. Introd. ad. Phil. Nat. tom. ii. p. 884. 4to.

M. Amontons, and others, we have already obferved, attribute the rarefaction of the air wholly to the fire contained in it; and therefore, by increafing the degree of heat, the degree of rarefaction may be carried ftill farther than its fpontaneous dilatation. Air is expanded $\frac{1}{3}$ of its bulk by boiling water. Hift. Acad. Sc. 1699.

Dr. Hales found that the air in a retort, when the bottom of the veffel was juft beginning to be red hot, was expanded through twice its former fpace, and in a white, or almoft melting heat, it occupied thrice its former fpace; but Mr. Robins found, (New Principles of Gunnery, ch. 1. prop. 5. p. 12.) that air was expanded by the heat of iron, juft beginning to be white, to four times its former bulk. Thus we account for the apparent inflation of a flaccid bladder, when it is warmed by the fire, and on this principle depend the ftructure and office of the THERMOMETER, and alfo the formation and afcent of air-balloons. See AEROSTATION.

M. Amontons firft difcovered that air will expand, in proportion to its denfity, with the fame degree of heat. On this foundation, the ingenious author has a difcourfe, to prove, 'that the fpring and weight of the air, with a moderate degree of warmth, may enable it to produce even 'earthquakes, and other of the moft vehement commotions 'of nature.'

According to the experiments of this author, and M. de la Hire, a column of air on the furface of the earth, 36 fathoms high, is equal in weight to three lines depth of mercury; and it is found, that equal quantities of air poffefs fpaces reciprocally proportioned to the weights with which they are preffed; the weight of the air, therefore, which would fill the whole fpace poffeffed by the terreftrial globe, would be equal to a cylinder of mercury, whofe bafe is equal to the furface of the earth, and its height containing as many times three lines, as the atmofpherical fpace contains orbs equal in weight to 36 fathoms of that wherein the experiment was made.—Hence, taking the denfeft of all bodies, *e. gr.* gold, whofe gravity is about 14,630 times greater than that of air in our orb, it is eafy to compute, that this air would be reduced to the fame denfity as gold, by the preffure of a column of mercury 14,630 times 28 inches high, *i. e.* 409,640 inches, fince the bulks of air, in that cafe, would be in the reciprocal ratio of the weights by which they are preffed. Thefe 409,640 inches, therefore, exprefs the height at which the barometer muft ftand, where the air would be as heavy as gold, and the number 2 [illegible] lines, the thicknefs to which our column of 36 fathoms of air would be reduced in the fame place.

Now, we know, that 43,528 fathoms, which is the depth, where the above preffure, and confequent reduction take place, are only the 74th part of the femidiameter of the earth; and, therefore, beyond that depth, whatever matter exifts, it muft be heavier than gold. It is not improbable, therefore, that the remaining fphere of 6,451,538 fathoms diameter may be full of denfe air, heavier by many degrees than the heavieft bodies which we know. Hence, again, as it is proved, the more air is compreffed the more does the fame degree of fire increafe the force of its fpring, and render it capable of a proportionably greater effect; we may infer, that a degree of heat, which in our orb can only produce a moderate effect, may have a very violent one in fuch lower orb; and that, as there may be many degrees of heat in nature, beyond that of boiling water, it is probable there may be fome, whofe violence, thus affifted by the weight of the air, may be fufficient to tear afunder the folid globe. Mem. de l'Acad. an. 1703. See EARTHQUAKES.

This elaftic property of air is fuppofed by many philofophers to depend on the figure of its corpufcles, which they apprehend to be ramous; fome maintain that they are fo many minute *flocculi*, refembling fleeces of wool; others conceive them rolled up like hoops, and curled like wires, or fhavings of wood, or coiled like the fprings of watches, and endeavouring to reftore themfelves in virtue of their texture: fo that to produce air, muft be to produce fuch a figure and difpofition of parts; and thofe bodies only are

proper subjects, which are susceptible of such disposition; which fluids, from the smoothness, roundness, and slipperiness of their parts, are not.

But Sir Isaac Newton (Optics, p. 371.) explains the matter otherwise; such a texture, he thinks, by no means sufficient to account for that vast power of elasticity observed in air, which is capable of diffusing itself into above a million of times more space than it before possessed.—But, as all bodies are shewn to have an attractive and repelling power; and as both these are stronger in bodies, the denser, more compact, and solid they are; hence it follows, that when by heat, or any other powerful agent, the attractive force is surmounted, and the particles of the body separated so far as to be out of the sphere of attraction; the repelling power which then commences makes them recede from each other with a strong force proportionable to that with which they before cohered; and thus they become permanent air. And he has proved, that particles, endeavouring to recede from each other with forces reciprocally proportional to the distance between their centres, will compose an elastic fluid, whose density shall be proportional to its compression. Hence, says the same author, it is, that as the particles of permanent air are grosser, and rise from denser bodies, than those of transient air, or vapour, true air is more ponderous than vapour; and a moist atmosphere is lighter than a dry one.

The elastic power of the air above illustrated and evinced, is the second great source of the effects of this important fluid. By this property, it insinuates itself into the pores of bodies, and by possessing this prodigious faculty of expanding, which is so easily excited, it must necessarily put the particles of bodies into which it insinuates itself into perpetual oscillations. Indeed, the degree of heat, and the air's gravity and density, and consequently its elasticity and expansion, never remaining the same for the least space of time, there must be an incessant vibration, or dilatation and contraction of all bodies.

We observe this reciprocation in several instances, particularly in plants, the tracheæ, or air-vessels of which perform the office of lungs; for the contained air alternately expanding and contracting, as the heat increases or is diminished, by turns compresses the vessels, and eases them again: and thus promotes a circulation of their juices. See Air-*vessels*.

Hence, we find, that no vegetation nor germination will proceed *in vacuo*. Indeed beans have been observed to grow a little tumid therein; and this has led some to attribute that to vegetation, which was really owing to no other cause than the dilatation of the air within them.

The air is very instrumental in the production and growth of vegetables, not only by invigorating their several juices, while in an elastic active state, but also by greatly contributing in a fixed state to the union and firm connection of their several constituent parts, and by supplying them with that food or pabulum, which contributes to their growth.

From the same cause it is, that the air contained in bubbles of ice, by its continual action, bursts the ice; and thus also, as well as by the expansion of freezing fluids, glasses and other vessels frequently crack, when their contained liquors are frozen. Thus also, entire columns of marble sometimes cleave in the winter time, from some little bubble of included air's acquiring an increased elasticity: and to this it is owing, that few stones will bear to be heated by the fire without cracking by the expansive force of the air confined within their pores. From the same principle arise *putrefaction* and *fermentation;* neither of which will proceed, even in the best disposed subjects, *in vacuo*.

Since we find such great quantities of elastic air, generated in the solution of animal and vegetable substances, a good deal must constantly arise from the dissolution of these elements in the stomach and bowels, which is much promoted by it: and respiration, and even animal life, depend in a great measure upon the air.

In reality, all natural corruption and alteration seem to depend on air; and metals, particularly gold, only seem to be durable and incorruptible, in virtue of their not being pervious to air.

Air, *effects of the different ingredients of*. Air not only acts by its common properties of gravity and elasticity, but there are numerous other effects, arising from the peculiar ingredients of which it consists.

Thus, 1. It not only dissolves and attenuates bodies by its pressure and attrition, but as a *chaos* containing all kinds of menstrua, and consequently possessing powers for dissolving all bodies. It is known that iron and copper readily dissolve, and become rusty in air, unless well defended with oil. Boerhaave assures us, that he has seen pillars of iron so reduced by air, that they might be crumbled to dust between the fingers; and as for copper, it is converted by the air into a substance much like the verdigrise produced by vinegar.

Mr. Boyle relates, that in the southern English colonies the great guns rust so fast, that after lying in the air for a few years, large cakes of *crocus martis* may be separated from them. Acosta adds, that in Peru the air dissolves lead, and considerably increases its weight. Yet gold is generally esteemed indissoluble by air; being never found to contract rust, though exposed to it ever so long. In the laboratories of chemists, however, where *aqua regia* is prepared, the air becoming impregnated with an unusual quantity of this menstruum, gold contracts a rust like other bodies.

Stones also undergo the changes incident to metals.—Thus, Purbeck stone, of which Salisbury cathedral consists, is observed gradually to become softer, and to moulder away in the air; and Mr. Boyle gives the same account of Blackington stone. He adds, that air may have a considerable operation on vitriol, even when a strong fire could act no further upon it And he has found, that the fumes of a corrosive liquor work more suddenly and manifestly on a certain metal, when sustained in the air, than the menstruum itself did, which emitted fumes on those parts of the metal which it covered; referring to the effects of the effluvia of vinegar on copper.

The dissolving power of air is increased by heat, and by other causes. It combines with water; and, by access of cold, deposits part of the matter which was kept dissolved in it, by a greater degree of heat. Hence the water, by being deposited and condensed upon any cold body, such as glass, &c. in windows, forms fogs, and becomes visible. Air, likewise, has been supposed, by means of its dissolving power, to accelerate evaporation and distillation.

2. Air volatilizes fixed bodies. Thus, sea-salt, being first calcined, then fused by the fire, and when fused, exposed to the air to liquify; when liquified set to dry, and then fused again, repeating the operation, will, by degrees, be almost wholly evaporated; nothing but a little earth remaining. Helmont mentions it as an arcanum in chemistry, to render fixed salt of tartar volatile; but this is easily affected by air alone: for, if some of this salt be exposed to the air, in a place replete with acid vapours, the salt draws the acid to itself, and when saturated with it, is volatile.

3. Air also fixes volatile bodies. Thus, though spirit

of nitre, or aquafortis, readily evaporates by the fire: yet if there be any putrefied urine near the place, the volatile spirit will be fixed, and fall down in form of AQUA SECUNDA.

4. Air brings many quiescent bodies into action; *i. e.* excites their latent powers. Thus, if an acid vapour be diffused through the air, all the bodies of which that is the proper menstruum, being dissolved by it, are brought into a state proper for action.

In the various operations of chemistry, air is a very necessary and important agent, the result of particular processes depending on its presence or absence, on its being open or enclosed. Thus the parts of animals and vegetables can only be calcined in open air; in close vessels they never become any other than black coals. And these operations are effected by the changes to which the air is liable. Many instances might be alledged to this purpose. Let it suffice to observe, that it is very difficult to procure oil of sulphur, *per campanam*, in a clear dry atmosphere; but in thick moist air it may be obtained with greater ease, and in larger quantities. So pure well-fermented wine, if it be carried to a place where the air is replenished with the fumes of new wine, then fermenting, will begin to ferment afresh.

The changes in the air arise from various causes, and are observable not only in its mechanical properties, such as gravity, density, &c. but in the ingredients that compose it. Thus, at Fashlun, in Sweden, noted for copper-mines, the mineral exhalations affect the air in such a manner, as to discolour the silver coin in purses; and the same effluvia change the colour of brass. In Carniola, Campania, &c. where are mines of sulphur, the air sometimes becomes very unwholesome, which occasions frequent epidemic diseases, &c.

The effluvia of animals also have their effect in varying the air, as is evident in contagious diseases, plagues, murrains, and other mortalities, which are spread by an infected air

The sudden and fatal effect of noxious vapours has generally been supposed to be principally, if not wholly, owing to the loss and waste of the *vivifying spirit of air*. But Dr. Hales attributes this effect to the loss of a considerable part of the *air's elasticity*, and to the grossness and density of the vapours with which the air is charged. He found, by an experiment made on himself, that the lungs will not rise and dilate as usual, when they draw in such noxious air, the elasticity of which has been considerably diminished. For having made a bladder very supple by wetting it, and then cutting off so much of the neck as would make a hole wide enough to admit the biggest end of a large fosset, to which the bladder was bound; and then having blown the bladder, he put the small end of the fosset into his mouth, and, at the same time, pinched his nostrils so close, that no air might pass that way, and he could only breathe to and fro the air contained in the bladder, which, with the fosset, contained seventy-four cubic inches. In less than half a minute, he found a considerable difficulty in breathing; and at the end of a minute, the bladder was become so flaccid, that he could not blow it above half full, with the greatest expiration which he could make; and at the same time, he could plainly perceive that his lungs were much fallen, in the same manner as when we breathe out of them all the air we can at once. Hence he concluded, that a considerable quantity of the elasticity of the air was destroyed; and that when the suffocating quality of the air was the greatest, it was with much difficulty that he could dilate his lungs in a very small degree. From this, and several other experiments, he inferred, that the life of animals is preserved rather by the elastic force of the air acting on their lungs than by its vivifying spirit; and that candles and matches cease to burn, after having been confined in a small quantity of air, not because they have rendered the air effete by consuming its vivifying spirit, but because they have discharged a great quantity of acid fuliginous vapours, which partly destroy its elasticity, and retard the elastic motion of the remainder, He likewise found, that air, which passed through cloths dipped in vinegar, could be breathed to and fro as long again as the like quantity of air, which was not thus purified; so that sprinkling the decks of ships with vinegar may refresh the air; and this is confirmed by experience. But where the corruption of the air is much greater, as in close prisons, &c. nothing can be an adequate and effectual remedy but a VENTILATOR. He observed, likewise, that air is not disqualified for respiration merely by the additional moisture which it receives, but by some bad quality in that moisture. See his Statical Essays, vol. i. p. 250. vol. ii. p. 320, &c.

Dr. Priestley observes, that, when animals die upon being put into air, in which other animals have died, after breathing in it as long as they could, it is plain that the cause of their death is not the want of any *pabulum vitæ*, which has been supposed to be contained in the air; but because the air is impregnated with something stimulating to their lungs; for they almost always die in convulsions, and are sometimes affected so suddenly, that they are irrecoverable after a single inspiration. And he has found the same effect from many other kinds of noxious air. He concludes, from subsequent experiments, that the air becomes phlogisticated in its passage through the lungs, by means of the blood. Experiments and Observations on Air, vol. i. p. 71. vol. ii. p. 31. vol. iii. p. 55. See AZOT, BLOOD, and RESPIRATION.

Vegetables likewise produce a change in the state of the air. Thus when a great part of the clove trees, which grow so plentifully in the island of Ternate, was felled at the solicitation of the Dutch, in order to heighten the value of that fruit, such a change ensued in the air, as shewed the salutary effects of the effluvia, or rather of the vegetation of the clove-trees, and their blossoms; the whole island soon after they werecut down, being exceeding sickly. See AZOT.

The air is also liable to alterations from the season of the year. Thus few subterraneous effluvia are emitted in the winter, because the pores are locked up by the frost, or covered by snow; the subterraneous heat being at work, and preparing a heat to be discharged in the ensuing spring. Again, from the winter solstice to the summer solstice, the sun's rays become more and more perpendicular, and consequently their impulse on the earth's surface more powerful; so that the glebe, or soil, is more and more relaxed, softened, and putrefied, till he arrives at the tropic; where, with the force of a chemical agent, he resolves the superficial parts of the earth into their constituent principles, water, oil, salt, &c, which are all swept away into the atmosphere.

The height and depth of the air produce a farther alteration; the exhalations not rising high enough in any great quantity, to ascend above the tops of high mountains.

From some experiments with air-balloons, it has been proved, that the air of the higher regions is more impure than that at the surface of the earth; which is reasonably ascribed to the oxygen supplied by vegetation to the lower and contiguous stratum of air.

Nor must drought and moisture be denied their share, in varying the state of the atmosphere; in Guinea, the heat, with the moisture, conduces so much to putrefaction, that the purest white sugars are often full of maggots; and their

drugs soon lose their virtue; and many of them grow verminous: it is added, that in the island of St. Jago, they are obliged to expose their sweet-meats daily to the sun, in order to exhale the moisture contracted in the night, which would otherwise occasion them to putrefy.

On this principle depend the structure and use of the HYGROMETER.

For the refracting power of air; see REFRACTION.

After all, some of our more curious and penetrating naturalists have observed certain effects of air, which do not appear to follow from any of the properties, or materials above recited. In this view, Mr. Boyle has composed a treatise of suspicions about some unknown properties of the air. The phenomena of fire and flame *in vacuo* seem, according to him, to argue some unknown vital substance, diffused through the air, on account of which that fluid becomes so necessary to the subsistence of flame. Buffon supposes that air is necessary to the subsistence of fire, because it is most adapted to acquire that expansive motion, which is the principal property of fire. On this account fire combines with air; in preference to any other substance, and in a more intimate manner, as being of a nature most nearly approaching to its own; and therefore air is the proper aliment and most powerful assistant of fire. Hist. Nat. Supp. vol. i.

According to Dr. Priestley, the air is a menstruum for the phlogiston emitted by burning bodies; which must cease to burn when that menstruum is saturated with it. And he accounts in the same manner for the suffocation of animals in a confined space. When the phlogiston, emitted by burning bodies and breathing animals, can no longer be absorbed by the ambient air, both life and flame are extinguished. Exp. and Obs. &c. vol. i.

For the modern hypothesis, with regard to this subject, see COMBUSTION and PHLOGISTON.

Thus we find, that many causes combine to produce very considerable alterations in the state of the air, whereby it becomes less fit for respiration, and other purposes of nature; and if there were no provision for restoring its salubrity, it must, in time, become universally injurious and fatal. Dr. Priestley, in the course of his inquiries on this subject, has discovered the great restoratives, which are provided for this purpose. One of these is vegetation. In order to ascertain this fact, he put a sprig of mint, in a vigorous state, under a glass jar, inverted in water; and he found, contrary to his expectation, that this plant not only continued to live, though in a languishing way, for two months; but that the confined air was so little corrupted by the effluvia of the mint, that it would neither extinguish a candle, nor kill a small animal, which he conveyed into it. He found, likewise, that air, vitiated by a candle left in it till it was burnt out, was perfectly restored to its quality of supporting flame, after another sprig of mint had vegetated in it for some time. And, in order to shew that the aromatic flavour of the plant had no share in producing this effect, he observed, in a variety of other experiments, that vegetables of an offensive smell, and even such as had scarce any smell at all, but were of a quick growth, proved the best for this purpose. Nay, more, the virtue of growing vegetables was found to be an antidote to the baneful quality of air, corrupted by animal respiration and putrefaction; and he infers from a number of similar facts, that the injury, which is continually done to the atmosphere, by the respiration of so many animals, and the putrefaction of such masses of both vegetable and animal matter, is, in part at least, repaired by the vegetable creation; and notwithstanding the prodigious mass of air that is corrupted daily by the above mentioned causes; yet, if we consider the immense profusion of vegetables upon the face of the earth, growing in places suited to their nature, and consequently at full liberty to exert all their powers, both inhaling and exhaling, it can hardly be thought, that the remedy is not adequate to the evil. Dr. Franklin, in a reflection on this discovery, expresses his hope, that it will give some check to the rage of destroying trees that grow near houses, which has accompanied our late improvements in gardening, from an opinion of their being unwholesome; adding, from long observation, that there is nothing unhealthy in the air of woods; "since the Americans have their country habitations in the midst of woods, and no people on earth enjoy better health, or are more prolific." Dr. Priestley has since discovered that light is necessary to enable plants to purify air: however, pure air is not produced by light or plants, but only by the purification of the impure air to which the plants have access. Obs. and Exp. on Air, vol. v. p. 18, 24, &c.

The sea, and other large bodies of water, are the second resource, which nature has provided for restoring the salubrity of corrupted air. Dr. Priestley found, that all kinds of noxious air were restored by continued agitation in a trough of water; the noxious effluvia being first imbibed by the water, and thereby transmitted to the common atmosphere. And he hence concludes, that the agitation of the sea, and of large lakes and rivers, must be highly useful for the purification of the atmosphere; the putrid matter being absorbed by the water, and imbibed by marine, and other aquatic plants, or applied to purposes yet unknown. Exp. and Obs. vol. i. sect. 2. and 4.

This ingenious philosopher apprehends, that the agitation of water, and the vegetation of plants, purify noxious air, by absorbing part of the phlogiston with which it is loaded; and that this phlogistic matter is the most essential part of the food and support of both vegetable and animal bodies. Ib. vol. i. p. 138, 139.

Dr. Priestley, improving upon the experiments and investigations of Boyle, Hales, Brownrigg, Black, Macbride, Cavendish, and others, has discovered many species of air, extracted by various processes from different kinds of substances; of which a summary account will be given in the course of this work. See also his curious and valuable Experiments and Observations on different Kinds of Air, in five volumes. And for a compendium of the history of discoveries on this subject, Lavoisier's Essays Physical and Chemical, vol. i.

For the resistance of the air, see RESISTANCE.

AIR, *undulation* of. See SOUND and UNDULATION.

AIR, in *Chemistry*. See GAS.

AIR, *Atmospheric*, *common air*, *Gas atmospherique*, Fr. Atmospheric air does not appear to have been the subject of chemical investigation before the time of Boyle; for though Aristotle, Pliny, and Paracelsus have written largely concerning this fluid, they have confined themselves to the imperfect examination of some of its physical properties, to the mention of a few obvious facts, and to the invention of hypotheses, which, as they do not profess to be founded on experiment, may, in the present state of knowledge, be safely neglected.

It was, indeed, natural, that the great improver of Otto Guericke's original air-pump, fond as he was of chemical pursuits, should exercise his talents in researches on the properties of the atmosphere, more especially as, from the number of substances continually assuming the form of vapour, it was not improbable that common air should prove a very heterogeneous and easily decomposable mixture. The

difficulty, however, of separating, by the only method then known, a portion of air from the rest of the atmosphere, and the necessary uncertainty of the first rude attempts to operate upon an invisible elastic substance, occasioned the progress of discovery in this department of chemical science to be unusually slow. The following facts, however, were ascertained by Boyle, which, when we consider the numerous obstacles from bad and imperfect apparatus that he had to contend with, are highly creditable to his industry and sagacity. He proved, that the presence of air was necessary to combustion and to animal life, by shewing, that in the exhausted receiver flame was almost immediately extinguished, and various small animals, and even fish, while in water, were in a short time killed: that the same phenomena take place, but more gradually, in a confined portion of atmospheric air; and that the death of animals, in this situation, was not owing to the heated exhalations from their bodies, as was then supposed, since the same effects took place when the apparatus was put into a frigorific mixture: he also ascertained, that animals live longer, *ceteris paribus*, in a given bulk of condensed than of rarefied air. On account of the imperfection of his apparatus, he was induced to believe, that no absorption of air took place in respiration; and he appears to have had no suspicion that pure atmospheric air was a compound substance.

Immediately after Boyle, succeeded Mayow, unquestionably the greatest chemical genius of that age, but whose works, by a singular fatality, excited little or no interest among his contemporaries, and were soon totally forgotten. In this state of unmerited neglect they remained for more than a century; and it is only within a very few years, that the public attention has been directed to the writings of a philosopher, who nearly anticipated those discoveries of Priestley, Lavoisier, and Cavendish, upon which are based almost all the modern improvements in chemistry. The first great improvement of Mayow in the analysis of atmospheric air, was the invention of a proper apparatus; for this purpose, rejecting the use of the air-pump, he made choice of glass jars, inverted in water, as the best method of confining the gasses upon which he experimented. Setting out from the facts discovered by Boyle, he argues, that since a lighted candle is extinguished much sooner in an exhausted receiver than in the same when filled with air, there must be something contained in the atmosphere necessary to the continuance of flame; and that a candle, in confined air, is not suffocated by its own fuliginous exhalations, but dies away for want of an aerial pabulum. The necessity of air to combustion is also proved, says he, from the impossibility of kindling a combustible body in vacuo by the concentrated solar rays, or by any other method. Having established this first position, he proceeds to infer, that it is not the whole air but only its more active particles, that are capable of supporting flame, because a candle goes out in confined air, while yet the greatest part of the elastic fluid remains unconsumed. Also, since sulphur, when mixed with nitre becomes capable of inflammation in vacuo, or even under water, it follows that nitre and atmospherical air contain some substance in common, which he calls *fire-air* particles *(particulæ igneo-aereæ.)* He next determined the analogy between flame and animal life; and shewed, that each depended for their continuance on a supply of fire-air particles: that there was an actual consumption of air in combustion and respiration he proved, by the rise of water in the jars in which a live animal or a lighted candle was inclosed; and that the loss of bulk was owing to the abstraction of fire-air, appeared from the inability of the residue to support animal life. He also inferred, that the fire-air particles were the heaviest part of atmospheric air, because, if two mice or two candles were confined in a tall cylindrical jar, inverted in water, so as that one should be near the upper part of the vessel, and the other at the bottom, the upper one, whether a candle or animal, would be extinguished some time before the lower one. With regard to the proportion of fire-air in the atmosphere, he only observed, that air rendered unfit for combustion by the breathing of an animal, lost about one fourteenth of its bulk; at the same time remarking, that there was probably only a part of the fire-air consumed: he afterwards, indeed, found, that the solution of iron in aquafortis occasioned a diminution of about 25 *per cent.* in atmospheric air; but though, in this case, he produced nitrous gas, and thus abstracted the oxygen of the atmosphere, yet, as he himself draws no conclusions from it, we should rather consider this as an accident than a discovery. Mayow never obtained the fire-air of the atmosphere in a separate state, and therefore was unable to confirm his analysis of atmospheric air by the synthetical proof; nevertheless, he was warranted by a very high probability in affirming that the atmosphere consisted of two kinds of air, of which the igneo-aerial was in the proportion of at least one to 13; that it exceeded the other part in its specific gravity, and was absolutely essential to the continuance of flame and animal life. The influence, however, of the prevalent hypothesis was at that time too strong to be shaken by sober experiment; and the labours and very name of Mayow, shortly sunk into oblivion: the atmosphere was still supposed to be an undecomposable element, and its effect on chemical processes was very generally overlooked.

In 1774, exactly a century after the publication of Mayow's work, the important discovery of dephlogisticated air, by Dr. Priestley, took place. This philosopher having inclosed some *mercurial precipitate per se*, in a jar filled with mercury, and inverted over the same, procured from it, by means of heat, a quantity of gas, in which a candle burnt with an enlarged flame, and increased light: the coincidence of this, with the effect produced by dephlogisticated nitrous gas in the same circumstances, as had been already observed by Dr. Priestley, induced him to believe that there was some common principle in nitrous acid and atmospherical air; and this suspicion was still further confirmed by the discovery, that common *red precipitate*, which is prepared by means of nitrous acid, yielded dephlogisticated air in the same manner as the precipitate *per se*. Hence, too, he concluded, that pure atmospherical air was not an element, and that dephlogisticated air was that one of its component parts to which the continuance of flame and animal life was entirely owing. Thus we find, both Mayow and Priestley arriving at the same general conclusions, through the medium of entirely different experiments; the fire-air of the one, and the dephlogisticated air of the other, being only two words for the same substance: the experiments of the latter possess, however, this capital superiority, that they exhibit in a separate uncombined state, that vital part of the atmosphere, the existence of which was only to be inferred from those of the former. There yet remained, however, for the complete proof of the composition of the atmosphere, that a part of it should be actually decomposed, so as to shew its elements separated; and then, by their union, to recompose atmospherical air. This deficiency was supplied by Lavoisier. He confined a few ounces of mercury and a certain portion of atmospherical air in a proper glass apparatus, and exposed the mercury for 12 days to a heat nearly equal to that of ebullition; during this period a part of the mercury was converted into a red oxyd, a certain portion of

the air disappeared, the remainder was incapable of supporting flame, and the weight of the red oxyd exactly corresponded with the loss sustained by the mercury and the air; this red oxyd, being then heated in a small retort, was decomposed into running mercury and a gas which exhibited all the properties of dephlogisticated air; finally, this air, being mingled with the unrespirable residue, recomposed atmospherical air. From these and various other similar experiments, it appeared, that the lower part of the atmosphere consists of 27 parts OXYGEN *gas*, and 73 of a mephitic air, which, upon a further analysis, yielded about 72 parts of AZOTIC *gas*, and one of CARBONIC *acid*. These experiments will be further detailed under the term EUDIOMETRY.

From the slight adherence of these gasses with each other in the air, it is probable that they are not so much in a state of combination as of intimate mixture; and hence there are scarcely any chemical actions produced by the atmosphere, which are not more properly referable to some one or other of its constituent parts.

Atmospherical air, as such, is soluble in water; from which it may be separated by the action of the air-pump, or by long boiling or distillation; hence fish, confined in fresh distilled water, soon die for want of air: if, however, the water has been previously exposed to the atmosphere, a sufficient portion is absorbed to supply the demands of these animals. In like manner water is soluble in air, but the proportion of this must necessarily vary according to the differences in temperature and barometrical pressure. Boyle's works, vol. ii. Mayow, Tractatus, &c. Priestley on Air. Lavoisier's Elements.

AIR, *factitious.* While pneumatic chemistry was in its infancy, all those elastic fluids produced in chemical experiments, were distinguished by this appellation from the air of the atmosphere; since, however, these factitious airs have acquired peculiar names, the term has fallen into disuse.

AIR, ACID. } See MURIATIC ACID.
—— MARINE. }

AIR, FIXED. }
—— FIXABLE. } See CARBONIC ACID.
—— MEPHITIC. }

AIR, VITRIOLIC ACID, See SULPHUREOUS ACID.

AIR, FLUORIC ACID. } See FLUORIC ACID.
—— SPARRY ACID. }

AIR, DEPHLOGISTICATED MARINE. See OXYMURIATIC ACID.

AIR, VEGETABLE ACID. See ACETOUS ACID.

AIR, NITROUS. See NITROUS GAS.

AIR, DEPHLOGISTICATED NITROUS. See NITROUS OXYD.

AIR, MEPHITIC ATMOSPHERICAL. }
—— PHLOGISTICATED. } See AZOT.
—— NITROGENOUS. }

AIR, VITAL. }
—— PURE. }
—— FIRE. } See OXYGEN.
—— DEPHLOGISTICATED. }

AIR, INFLAMMABLE. See HYDROGEN.

AIR, SULPHURATED INFLAMMABLE. } See HYDROGEN
—— HEPATIC. } *sulphurated.*

AIR, HEAVY INFLAMMABLE. See HYDROGEN *carbonated,* or CARBON, *gasseous oxyd of.*

AIR, ALKALINE. See AMMONIA.

For an account of Dr. Priestley's numerous experiments and observations on these several species of air, the reader is referred to the excellent work already cited.

Air-Gun

Air-*gun*, or *Wind-gun*, a machine which ſerves to explode bullets, and other ſhot, with great violence, by the expanſive force of the air. This ſort of implement, charged with air, has an effect ſcarcely inferior to that of a common fire-arm charged with gun-powder; but it diſcharges itſelf with a much leſs report; and it is this which probably gave occaſion to the fable of white gun-powder. The firſt account of an air-gun, that has been noticed, is found in the Elemens d'Artillerie of David Rivaut, who was preceptor to Louis XIII. of France. He aſcribes the invention to one Marin, a burgher of Liſieux, who preſented one to Henry IV.

The common air-gun (*Pneumatics, Plate* iii. *fig*. 14.) is made of braſs, and has two barrels: the inſide barrel K A of a ſmall bore, from which the bullets are ſhot, and a larger barrel E C D R on the outſide of it. In the ſtock of the gun there is a ſyringe, S M N P, whoſe rod M draws out to take in air, and piſton S N drives the air before it through the valve E P into the cavity between the two barrels. The ball K is put down into its place in the ſmall barrel with the rammer, as in another gun. There is another valve at S L, which, being opened by the trigger O, permits the air to come behind the bullet, ſo as to drive it out with great force. If this valve be opened and ſhut ſuddenly, one charge of condenſed air may make ſeveral diſcharges of bullets; becauſe only part of the injected air will go out at a time; and a new bullet may be put into the place K; but if the whole air be diſcharged on a ſingle bullet, the ball

ball will be expelled more forcibly. This difcharge is effected by means of a lock *k l* (*fig.* 15.) placed here as in other guns; for the trigger being pulled, the cock *k* will go down, and drive a lever *o*, that will open the valve, and let in the air upon the bullet K.

An air-gun of the moft modern and approved conftruction is reprefented in *fig.* 16. A is the iron gun-barrel, with the lock, ftock, ram-rod, &c. of about the fize and weight of a common fowling-piece. Under the lock at *b* is a round fteel-tube, with a fmall moveable pin in the infide, which is pufhed out by the fpring of the lock, when the trigger *a* is pulled. To this tube, *b*, is fcrewed a hollow copper-ball, *c*, containing a fpring-valve at its aperture; and perfectly air-tight. Each gun has ufually two of thefe balls, which are fully charged with condenfed air by means of the condenfing fyringe B, *fig.* 17. Having rammed down the leaden bullet into the barrel, and fcrewed the copper ball home to the lock at *b*, let the trigger, *a*, be pulled, and the pin at *b* will be forcibly and inftantly driven out againft the valve in the ball, and will thus liberate a portion of the condenfed air; which, rufhing up through an aperture in the lock into the barrel immediately before the ball, will impel it to the diftance of, at leaft, 60 or 70 yards. By recocking the piece, another difcharge may be immediately made, and thus repeated 15 or 16 times, with a very fmall hiffing noife, which at a diftance is not audible. The condenfed air is forced into the ball by the following apparatus. The ball, *c*, is fcrewed to the brafs fyringe B (*fig.* 17.) quite clofe. In this fyringe is adapted a moveable pifton and iron rod, *a*, at the end of which is a ftrong ring, into which is placed a ftout iron rod, *k k*: upon this rod the feet are firmly placed, and the hands are applied to the wooden handles, *i i*, fixed to the fyringe. By fteadily moving the barrel B, up and down on the rod *a*, the ball, *c*, will become charged with condenfed air; and it is eafily known when it is filled to the utmoft by the irrefiftible action which the air makes againft the pifton, when you are working the fyringe. At the end of the rod *k*, is ufually an eight-fquare hole, which ferves as a key to make the ball faft on the fcrew, *b*, of the gun, and on the fyringe. The pifton-rod works air-tight by a collar of leathers on it, in the barrel, B; and therefore, when the barrel is pulled up, frefh air will rufh in at the hole *b*; when the barrel is pufhed down, the air in it can only pafs into the ball at top; the barrel being drawn upwards, the operation is repeated, until the condenfation is fo ftrong as to refift the action of the pifton.

Dr. Macbride (Exper. Eff. p. 81.) mentions an improvement of the air-gun by Dr. Ellis, in which the chamber for containing the condenfed air is not in the ftock, which makes the machine heavy and unwieldy, but has five or fix hollow fpheres belonging to it, of about three inches diameter, fitted to fcrew on the lock of the gun. Thefe fpheres are contrived with valves for confining the air, which is forced into their cavities, fo that a fervant can carry them ready-charged with condenfed air; and thus the gun of this conftruction is rendered as light and portable as one of the fmalleft fowling-pieces.

The *magazine air-gun* is an improvement of the common air-gun, invented by an ingenious artift called L. Colbe. By his contrivance ten bullets are fo lodged in a cavity, near the place of difcharge, that they may be drawn into the fhooting barrel, and fucceffively fhot fo quickly, as to be nearly of the fame ufe with fo many different guns; the only motion required, when the air has been previoufly injected, being that of fhutting and opening the hammer, and cocking and pulling the trigger. In *fig.* 18, is exhibited a fection of the gun, as large in every part as the gun itfelf; and fo much of its length is fhewn as is neceffary to give a complete idea of the whole. A E E is part of the ftock; G is the end of the injection fyringe, with its valve, H, opening into the cavity, F F F F, between the barrels. K K is the fmall or fhooting barrel, which receives the bullets, one at a time, from the magazine, E D, which is a ferpentine cavity, wherein the bullets, *b*, *b*, &c. are lodged, and clofed at the end D. The circular part, S I *s k* M *i*, is the key of a cock, having a cylindrical hole, I K, through it, equal to the bore of the fmall barrel, and forming a part of it in the prefent fituation. When the lock is taken off, the feveral parts, Q, R, T, S, W, &c. come into view, by means of which the difcharge is made, by pufhing up the pin, P *p*, which raifes and opens a valve, V, to let in the air againft the bullet, I, from the cavity, F F F; which valve is immediately fhut down again by means of a long fpring of brafs, N N. This valve, V, being a conical piece of brafs, ground very true in the part which receives it, will of itfelf be fufficient to confine the air. To make a difcharge, pull the trigger, Z Z, which throws up the feer, *y x*, and difengages it from the notch, *x*; upon which the ftrong fpring, W W, moves the tumbler, T, to which the cock is fixed. The end, *u*, of this tumbler bears down the end *v*, of the tumbling lever, R, which, by its other end, *m*, raifes the flat end, *l*, of the horizontal lever, Q, by which means the pin, P *p*, is pufhed up, and opening the valve, V, difcharges the bullet; all which is evident from a bare view of the figure.

To bring another bullet inftantly to fucceed I, there is a part H, called the hammer, reprefented in *fig.* 19. and *fig.* 20. which by a fquare hole goes upon the fquare end of the key of the cock, and turns it about fo as to place the cylindric bore of the key I *k*, in any fituation required.

Thus, when the bullet is in the gun, the bore of the key coincides with that of the barrel K K; but when it is difcharged, the hammer H is inftantly brought down to fhut the pan of the gun; by which motion the bore of the key is turned into the fituation *ik*, fo as to coincide with the orifice of the magazine; and upon lifting the gun upright, the ball next the key tumbles into its cavity, and falling behind two fmall fprings, *s s*, *fig.* 18. is by them detained. Then opening the hammer again, the ball is brought into its proper place, near the difcharging valve, and the bore of the key again coincides with that of the fhooting barrel. It appears how expeditious a method this is of charging and difcharging a gun; and if the force of condenfed air was as great as that of gunpowder, fuch an air-gun would actually anfwer the end of many guns, and prove the beft defence againft highwaymen or robbers; becaufe, when there is reafon to fufpect them, they might then make five or fix difcharges before the robber can come within piftol-fhot.

From the experiments of Mr. Robins, in his New Principles of Gunnery, (See Mathem. Tracts of Robins, by Wilfon, vol. i. p. 73.) it appears, that the force of gunpowder, at the moment of its explofion, is 1000 times greater than that of the elafticity of common air; and, therefore, that the latter may produce the fame effect with the former, its condenfation muft be 1000 times greater than that of its natural ftate. But as the velocities with which equal balls are impelled are directly proportional to the fquare roots of the forces, the velocity with which an air-gun, containing air condenfed only ten times, will project a ball, will be $\frac{1}{10}$th of that arifing from gun-powder; and if the air were condenfed 20 times, it would communicate a velocity of $\frac{1}{7}$th of that of gun-powder. In the air-gun, however, the refervoir of condenfed air is commonly very large, in proportion to the tube which

contains the ball, and its denfity will be very little altered by expanding through that narrow tube; confequently the ball will be urged by nearly the fame uniform force with that of the firft inftant: whereas the elaftic fluid of inflamed gun-powder, bears a fmall proportion to the barrel of the gun, and by dilating from the fmall portion of it near the but-end into a comparatively large fpace, its elaftic force will be proportionally weakened, and its action on the ball in the barrel will become gradually lefs and lefs. Hence it appears, that the air-gun will project its ball with a much greater proportional degree of velocity than that which is above ftated; infomuch that air condenfed ten times will produce a velocity not much inferior to that arifing from the gun-powder.

However, in this kind of gun, and in all cafes which require a very confiderable condenfation of air, it will be requifite to have the fyringe of a fmall bore, *viz.* not exceeding half an inch in diameter; becaufe the preffure againft every fquare inch is about 15 pounds, and againft every circular inch about 12 pounds. If, therefore, the fyringe be one inch in diameter, when one atmofphere is injected, there will be a refiftance of 12 pounds againft the pifton; when two, of 24 pounds; and when ten are injected, there will be a force of 120 pounds to overcome; whereas ten atmofpheres act againft the circular half inch pifton, whofe area is but one-fourth part fo big, with a force but one-fourth as great, *viz.* 30 pounds; or 40 atmofpheres may be injected with fuch a fyringe as well as ten with the other. Defaguliers's Exp. Phil. vol. ii. p. 398, &c. Martin's Phil. Brit. vol. ii. p. 189, &c. Adams's Lect. on Nat. and Exp. Phil. by Jones, vol. i. p. 133.

Air-*jacket*, a jacket of leather, furnifhed with bags or bladders of the fame material, inflated with air, and ferving to buoy up the perfon who wears it, and to prevent his finking in water, without any effort of fwimming. Thefe bags communicate with each other, and are filled with air by means of a leathern pipe, having at the end of it a ftop-cock, accurately ground, fo as to admit the injected air, and, when clofed, to prevent its efcape. The jacket muft be well moiftened with water before the bags are filled: otherwife the air will efcape through the pores of the leather.

Air-*lamp*, a pneumatic machine, formed by the combination of inflammable air and electricity, which, by turning a ftop-cock, produces a flame that may be reftrained or continued at pleafure. The contrivance of machines of this fort was fuggefted by the experiments of Mr. Volta, Dr. Ingenhouz, &c. The air-lamp is now conftructed in the following manner. A, (*Plate* iii. *Pneumatics*, *fig.* 21.) is a glafs jar for containing the inflammable air; B, an open glafs urn, that contains water, by the preffure of which the air is forced out of the jar A, through the brafs-pipe *a*; C, is the ftop-cock, fo perforated, that the water may defcend from B into A, and the air pafs out through the pipe *a*. By turning the bar of the ftop-cock to an horizontal pofition, the communication between the two veffels is clofed, and the paffage of the air obftructed; and by turning it into a vertical pofition, the communication is opened. The lower jar, A, is fupplied with inflammable air by means of the bladder, (*fig.* 22); and two bladders of this kind accompany each lamp. It is ufed in the following manner: Take off the cover D, from the lamp, and turn the ftop-cock upwards; then pour as much clear water into it as will fill the veffel, A, up to the pipe *a*; unfcrew this pipe, and in its ftead fcrew the fmall brafs piece (*fig.* 23.) and to this fcrew one of the ftop-cocks and bladder, (*fig.* 22.) With the bladder under one arm, one hand to the cock at C, and the other to that of the bladder, open the apertures and prefs the bladder at the fame time; and thus the air will be forced upon the water in A, and driven up the glafs pipe through the tube into B, with a bubbling noife. When the veffel, A, is thus charged with air, the ftop-cocks are to be turned, fo as to cut off the communication with the external air. Care muft be taken that the common atmofpheric air does not mix with the inflammable; for if a mixture of thefe airs were fired, the explofion would be great and dangerous.

The apparatus for lighting this lamp is of the electrical kind; and it is as follows. The mahogany bafis, E F, is a fort of box, about 12 inches fquare, and 5 inches deep; and in this is placed an electrophorus, confifting of a refinous cake *c*, and metallic plate *d*, which by a hinge at its back, admits of being pulled upwards and let down by the filken ftring *b*, connected both with it and with the ftop-cock C. When this cake is once excited, its electrical effect upon the metal plate will be continued for a long time. A metallic chain, G, communicates with a wire and ball *e*, paffing through a glafs tube below, in the box over the plate, and above with a fine wire paffing through a glafs tube. This upper wire is bent to about ⅛th of an inch diftance from the flame-pipe. It is evident that when the electrophorus in the box is previoufly excited, and the ftop-cock, C, turned, the filken ftring, *b*, will raife the metallic plate; and this will give an electric fpark to the ball and wire above, which will convey it inftantly to the flame-pipe, and inflame the air iffuing out of the pipe, in confequence of the preffure of the water in its defcent into the veffel A. The cock, C, being turned back, the flame ceafes; and turned again, appears; and will ferve to light a candle, match, &c. whenever it may be thought proper. The number of times in which light may be produced will be very great, and will depend on the quantity of the inflammable air in the veffel A. If the cock is not turned back, the flame will continue till the whole of the inflammable air is confumed. The light thus produced will be fufficient for reading a large print in the night, or feeing the hour by a watch. When the electrophorus is to be excited, the filken ftring, *b*, is unhooked from the plate, and the apparatus taken out of the box; and the metallic plate is lifted up, whilft, with a filken or dry cat-fkin rubber, you brifkly rub the furface of the refinous cake. About 20 revolutions in rubbing will be fufficient, fo that the plate will give a fpark to the knuckle about the diftance of an inch; and by the ftrength of the fpark the degree of excitation is to be eftimated. The filken ftring and fmall glafs tubes, through which the wire, G, paffes, fhould always be very dry, that the paffage of the electrical fpark may be quite perfect. The whole length of this apparatus is about 22 inches; but it may be made of any dimenfions. Dr. Ingenhouz ufed a fmall apparatus, conftructed upon a fimilar principle, in obtaining light for domeftic purpofes, both when at home and on his travels. Adams's Lecturs by Jones, vol. ii. p. 99, &c.

Air-*pipes*, a contrivance invented by Mr. Sutton, a brewer of London, for clearing the holds of fhips and other clofe places of their foul air. The principle upon which this contrivance is founded is well known. It is no other than the rarefying power of heat, which, by caufing a diminution of the denfity of the air in one place, allows that which is in contact with it to rufh in, and to be fucceeded by a conftant fupply from remoter parts, till the air becomes every where equally elaftic. If a tube, then, be laid in the well, hold, or any other part of a fhip, and the upper part of this tube be fufficiently

heated to rarefy the impending column of air, the equilibrium will be maintained by the putrid air from the bottom of the tube, which being thus drawn out, will be succeeded by a supply of fresh air from the other parts of the ship; and by continuing the operation, the air will be changed in all parts of the ship. Upon this principle, Mr. Sutton proposed to purify the bad air of a ship, by means of the fire used for the coppers, or boiling places, with which every ship is provided. Under every such copper or boiler there are two holes separated by a grate, one for the fire and the other for the ashes; and there is also a flue, communicating with the fire-place, for the discharge of the smoke. The fire, after it is lighted, is preserved by the constant draught of air through these two holes and the flue; and if the two holes are closed, the fire is extinguished. But when these are closed, if another hole communicating with any other airy place, and also with the fire, be opened, the fire will of course continue to burn. In order to clear the holds of the ships of the bad air, Mr. Sutton proposed to close the two holes above mentioned, *viz.* the fire-place and ash-place, with substantial iron doors, and to lay a copper or leaden pipe of sufficient size from the hold into the ash-place, and thus to supply a draught of air for feeding the fire; a constant discharge of air from the hold will be thus obtained, and fresh air will be supplied down the hatches, and by such other communications as are open into the hold. If other pipes are connected with this principal pipe, communicating either with the wells or lower decks, the air that serves to feed the fire will be drawn from such places.

In large ships, there is not only a copper, but a fire-grate, like those used in kitchens; behind this grate an iron tube might be fixed, and inserted quite through the brick-work and through the deck, so that one end of it might stand about a foot, or somewhat more, in the chimney above the brick-work, and the other made to enter into the hold or any other part of the ship. When the upper end of this tube is heated, the draught of air will be supplied from below, as in the other case. Mr. Sutton's practicable and useful contrivance was much opposed at its first proposal; and though his pipes were recommended by Dr. Mead and Mr. W. Watson, after several trials of their effect, they were very slowly introduced, and in process of time very much neglected. Mr. Sutton, after considerable delay, and with no small difficulty, obtained a patent for his invention.

Mr. Watson recommends the use of these pipes for the circulation of fresh air in houses, prisons, hospitals, wells, &c. And they have undoubtedly this obvious advantage, that by causing the putrid and noxious air to pass into the fire, they not only dissipate but destroy it. Phil. Trans. abr. vol. viii. p. 628. 630. Mead's Works, p. 397—437.

For other inventions adapted to the same purpose, see Air-*trunk*, Bellows, *Ship's*-lungs, Ventilator, *Blowing*-wheel, and Wind-*sails*.

Air-*pump*, a machine, by means of which the air may be exhausted out of proper vessels.

The use and effect of the air-pump is to make what we popularly call a *vacuum;* but this, in reality, is only a degree of rarefaction sufficient to suspend the ordinary effects of the atmosphere.

By this machine, therefore, we learn in some measure, what our earth would be without an atmosphere; and how much all vital, generative, nutritive, and alterative powers, depend upon it.

The principle on which the air-pump is constructed, is the elasticity of the air; as that on which the common, or water-pump is founded, is the gravity of the same air.

The structure of the air-pump is, in itself, more simple even than that of the water-pump.—The latter supposes two principles, gravity and elasticity likewise: so that the water-pump must first be an air-pump, *i.e.* it must rarefy the air before it can raise the water.—In effect, water being a dormant unelastic fluid, needs some external agent to make it ascend; whereas air ascends in virtue of its own elastic activity: its natural tendency is to separate and leave a vacuum; and all that remains for art is to prevent the ambient air from supplying the place of that which thus spontaneously escapes. To make water ascend, the force wherewith it is pressed downwards is either to be diminished or increased in one part more than another; like a balance *in æquilibrio*, one of whose scales may be made to rise, either by diminishing its own weight, or increasing that of the other; the water, therefore, recedes from the common centre of gravity by the very power with which it tends towards it indirectly or secondarily applied; because, two similar centripetal forces being made to act contrary to each other, what in the one over-balances the other must have the effect of a centrifugal force.—Whereas, the principle whereby air is rarefied or diminished, does not respect the centre of the earth, but the centres of its own particles; being no other than a certain implanted power, whereby they immediately tend to recede from each other.

The invention of this noble instrument, to which the present age is indebted for so many fine discoveries, is ascribed to Otto de Guericke, the celebrated consul of Magdeburg, who exhibited his first public experiments with it, before the emperor and the states of Germany, at the breaking up of the imperial diet at Ratisbon, in the year 1654: but his description of the instrument, and of the experiments performed with it, is contained in his "Experimenta nova Magdeburgica de Vacuo Spatio," and was not published before the year 1672, at Amsterdam.

Dr. Hooke and M. Duhamel, indeed, ascribe the invention of it to Mr. Boyle; but that ingenious author frankly confesses de Guericke to have been beforehand with him. In a letter which he wrote to his nephew, Lord Dungarvan, at Paris, about two years after Schottus's book was published, he introduces the acknowledgment of his obligation, for the discovery of this useful machine, to what he had heard of it, though he had not then perused it, by that well-applied passage of Pliny, *benignum est et plenum ingenui pudoris fateri per quos profeceris.* Some attempts, he assures us, he had made upon the same foundation, before he knew any thing of what had been done abroad: but the information he afterwards received from Schottus's Mechanica Hydraulico Pneumatica, published in 1657, wherein was an account of de Guericke's experiments, first enabled him to bring his design to any thing of maturity. From hence, with the assistance of Dr. Hooke, after two or three unsuccessful trials, arose a new air-pump more easy and manageable than the German one; and hence, or rather from the great variety of experiments that illustrious author applied it to, the engine came to be denominated *machina Boyliana*, and the *vacuum* produced by it, *vacuum Boylianum.*

Air-*pump, structure and use of the.* The basis or essential part in the air-pump, is a metalline tube, answering to the barrel of a common pump, or syringe; having a valve at the bottom, opening upwards; and a moveable piston or embolus, answering to the sucker of a pump, furnished likewise with a valve opening upwards. The whole must be duly fitted to a vessel as a recipient or receiver.

The rest being only circumstances chiefly respecting conveniency, have been diversified and improved from time

to time, according to the ſeveral views and addreſs of the makers.

In our further account of the air-pump, we ſhall trace the various alterations it has undergone from the rude and inconvenient conſtruction of Otto de Guericke to its preſent improved ſtate. Guericke's machine is exhibited in *Plate* iv. *Pneumatics*, *fig.* 24. It conſiſts of an iron three-legged frame, *a b c d f*, ſupporting a round iron plate, *b c*, in the middle of which is inſerted a braſs ſyringe, *g h*. The upper part of this ſyringe is furniſhed with a rim of lead, *y*, (*fig.* A.); and it is faſtened below by means of an iron ring, *k k*, and three iron arms, *o o o*, to the legs of the frame. Within the rim *y*, there is a braſs plate *m n*, (*fig.* B.) encompaſſed by a ring of leather, and fixed by three ſcrews which terminates upwards in a ſmall tube *n*, into which the pipe connected with the veſſel to be exhauſted is inſerted, as occaſion requires, and to which, on the lower ſide, is adapted a valve of leather, through which the air paſſes into the ſyringe. In this plate there is alſo another ſmall valve at *z*, opening upwards, through which it eſcapes. This plate is covered by a copper veſſel, *x x*, intended for containing water. The piſton of the ſyringe *s h*, (*fig.* 24, and *fig.* C.) is connected by a joint at *t*, with the iron rod *t u*, which is faſtened to the handle, *w u u*; and this moves round the pin at *w*, by which it is connected with one of the legs of the frame. In order to prevent air from entering into the ſyringe, a copper veſſel of water is ſuſpended by hooks to the arms, *o*, *o*, *o*, ſo that the lower part of the ſyringe at *k k*, and the piſton, may be always covered with water, when the machine is at work. The receiver, L, is a glaſs ſphere, adapted to a braſs cap, P P, which has a pipe with a ſtop-cock, *q r*; and this pipe is fitted to the tube, *n*, above mentioned. From this brief deſcription of the machine, its operation will be eaſily underſtood. When the piſton, *s h*, is depreſſed, the air will be expanded in the ſyringe, *g h*, and that of the receiver will deſcend into it through the valve in the lower ſurface of the plate, *m n*; but when the piſton is elevated, and the air is compreſſed, this valve ſhutting upwards will cloſe the paſſage to the receiver, and make its eſcape through the valve *z*, which opens upwards. In order to render the exhauſtion more complete, a ſmall exhauſting ſyringe is adapted to the plate, which is repreſented at *m*. See Guericke's Exper. Nov. Magdeb. Amſt. 1672. lib. iii. c. iv. and v. p. 77.

This machine, though it might be deemed an excellent contrivance at the time of its invention, when the doctrine of the elaſticity and expanſion of the air was new, had many defects which it is hardly neceſſary now to mention. The force neceſſary for working it was very great, and the progreſs of its operation very ſlow. Beſides, it was to be wrought under water, and it allowed of little change of ſubjects for experiments. Mr. Boyle, whoſe ideas of this machine, firſt ſuggeſted to him by Schottus's report of Guericke's conſtruction, were executed by Dr. Hooke, whom he then employed as his operator, removed ſome of theſe inconveniences and diminiſhed others.

The form of Mr. Boyle's air-pump appears in *Plate* iv. *Pneumatics*, *fig.* 25. It conſiſted of a ſpherical receiver, A, with a round hole at the top, whoſe diameter, B C, was about four inches; this was covered with a plate, having a braſs rim, D E, which was firmly cemented to the ring of glaſs that ſurrounded the hole; and to the tapering orifice of the braſs rim was adapted a braſs ſtopple, F G, ground ſo exactly as to exclude as much as poſſible the admiſſion of air. In the centre of the cover was a hole, H I, of about half an inch in diameter, provided with a ſocket, to which the braſs ſtopple, K, was ſo fitted as to prevent the entrance of air; and the lower part of this ſtopple was perforated with a hole, through which paſſed the ſtring, 8, 9, 10, for the convenience of moving to and fro the ſubjects of experiments. To the neck of the receiver a ſtop-cock, N, was faſtened; and to the ſhank of the cock, X, a tin-plate, M T U W, was ſo cemented as to preclude the admiſſion of air. The lower part of this machine conſiſted of a wooden frame with three legs, 1 1 1, and a tranſverſe board, 2 2 2, on which the pump reſted. The cylinder of this pump was caſt braſs; and it was fitted with a ſucker, 4 4, 5 5; of which one part, 4 4, was covered with ſhoe-leather, ſo as exactly to fill the cavity of the cylinder; and to this was faſtened the other part, which was a thick and narrow plate of iron, 5 5, ſomewhat longer than the cylinder, indented on one edge with narrow teeth, ſo as to admit the correſponding teeth of a ſmall iron nut, faſtened by two ſtaples to the under ſide of the tranſverſe board 2, 2, 2, on which the cylinder reſts; and this is turned to and fro by the handle, 7. The laſt part of this cylinder is the valve, R, conſiſting of a hole bored through at the top of the cylinder, ſomewhat tapering towards the cavity; into which hole is ground a tapering peg of braſs, to be thruſt in and taken out at pleaſure. In order to prevent more effectually the admiſſion of air, and to prepare the ſucker of the pump for motion, a quantity of ſallad oil was poured in at the top of the receiver and alſo into the cylinder. The operator, having fixed the lower ſhank, O, of the ſtop-cock into the upper orifice of the cylinder, turns the handle, and thus forces the ſucker to the top of it, ſo that no air may be left in its upper part. Then ſhutting the valve with the plug, and turning the handle the other way, he draws down the ſucker to the bottom of the cylinder, and thus its cavity, into which no air is admitted, will be in an exhauſted ſtate. By turning the ſtop-cock, and opening a paſſage between the cylinder and the receiver, the air contained in the one will deſcend into the other; and this air being prevented from returning, by turning back the key of the ſtop-cock, will be made to open the valve and to eſcape into the external air by forcing the ſucker to the top of the cylinder; by alternately moving the ſucker upward and downward, turning the key and ſtopping the valve, as occaſion requires, the exhauſtion may be continued. See Boyle's Works, by Birch, vol. i. p. 7—10.

Mr. Boyle has deſcribed a ſecond air-pump in the firſt continuation of his Phyſico-mechanical experiments. See his works, vol. iii. p. 180. This, like the former, had only one barrel, by which the receiver was exhauſted; but it was ſo contrived as to be every where ſurrounded with water, that the ingreſs of air might be more effectually prevented. Beſides, the receivers, which were of ſeveral forms and ſizes, were faſtened to an iron plate by means of a ſoft cement, ſo that they could be removed and changed at pleaſure. The interpoſition of a moiſtened leather for fixing them, does not ſeem at this time to have occurred to him.

Notwithſtanding all the precautions of Mr. Boyle, and his contrivances for excluding air by oil and leather, he found that the working of his pump by a ſingle barrel was laborious, on account of the preſſure of the atmoſphere, a great part of which was to be removed at every elevation of the piſton, when the exhauſtion was nearly completed: and he himſelf candidly acknowledges, that it was rarely and with great difficulty, that he was able to produce any great degree of rarefaction. This uſeful machine was gradually improved by Papin, Merſenne, Mariotte, and others; but the introduction of a ſecond barrel and piſton was the

principal improvement which it received about this period. To whom this was owing, it is not eaſy to decide: ſome aſcribe it to Dr. Hooke, others to Papin, and others again to Haukſbee. An engine of this kind, with a double tube, is deſcribed by Mr. Boyle, in the ſecond continuation of Phyſico-mechanical Experiments, (works, vol. iv. p. 510.); but the manner of working it, by means of a pulley and of iron ſtirrups or treddles, upon which the operator ſtood, muſt have been extremely inconvenient. However, by the uſe of a ſecond barrel and piſton, contrived to riſe and fall alternately with the other, and by the introduction of valves, which in this third air-pump of Mr. Boyle ſupplied the place of the plug and ſtop-cock which he had before uſed, as well as by the ſubſequent improvements of Haukſbee, the preſſure of the atmoſphere on the deſcending piſton always nearly balanced that of the aſcending one; ſo that the winch which worked them up and down was eaſily moved by a gentle force with one hand; and the exhauſtion was alſo made in much leſs time. See Haukſbee's Phyſico-Mechanical Experiments, p. i., &c. Mr. Vream, a pneumatic operator, employed by Deſaguliers, made an improvement in Haukſbee's air-pump, by reducing the alternate motion of the hand and winch to a circular one. In his method the winch is turned quite round, and yet the piſtons are alternately raiſed and depreſſed; by which the trouble of ſhifting the hand backwards and forwards, as well as the loſs of time, and the ſhaking of the pump, are prevented. See Deſagulier's Courſe of Exp. Philoſ. vol. ii. p. 378. For a brief account of the progreſſive improvements of the air-pump, ſee Cotes's Hydroſtatical and Pneumatical Lectures, lect. xii. p. 156, &c.

The ſtructure of the air-pump, thus improved, is repreſented in *Plate* v. *Pneumatics*, *fig* 33. It conſiſts of two braſs barrels or cylinders, *a a*, *a a*, which communicate with each other by the ciſtern *d d*, and with the receiver *o o o o*, which is ground level at the bottom, and ſet over a hole in the plate, by means of the bent pipe, *b b*. In theſe barrels the piſtons, which are faſtened ſo tight that no air can get between them and the barrels, are worked by a toothed wheel, turned by the handle, *b b*; and thus the racks, *c c*, with their piſtons, are worked alternately up and down. The gage tube, *l l*, is immerſed in a baſon of quickſilver *m*, at the bottom, and communicates with the receiver at the top; from which it may be occaſionally diſengaged by turning a cock; and *n* is another cock, by turning of which the air is again let into the exhauſted receiver, paſſing into it with a hiſſing noiſe. The action of the toothed wheel and piſtons is repreſented in *fig*. 34.

As the handle is turned backwards, it raiſes the piſton *d e*, in the barrel B K, by means of the wheel E, and rack D *d*: and as no air can get between the piſton and barrel, all the air above *d* is lifted up towards B, and a vacuum is made in the barrel from *e* to *b*; upon which part of the air in the receiver by its ſpring ruſhes through the hole in the braſs plate of the pump along the pipe G G, communicating with both barrels by the hollow trunk I H K, and puſhing up the valve *b*, enters into the vacant part *b e*, of the barrel B K. Then, as the handle, F, is turned forward, the piſton, *d e*, will be depreſſed in the barrel; and the air which had got into the barrel, finding no way of eſcape through the cloſed valve *b*, will aſcend through a hole in the piſton, and make its way into the external air through a valve at *d*; and it will be prevented by that valve from returning into the barrel, when the piſton is again raiſed. At the next elevation of the piſton, a vacuum is again made in the ſame manner as before, between *b* and *e*; upon which more of the air that was left in the receiver will get out by its ſpring, and flow into the barrel, B K, through the valve *b*. The other piſton and barrel act in the ſame manner; and as the handle, F, is turned backwards and forwards, it alternately raiſes and depreſſes the piſtons in their barrels; one being raiſed whilſt the other is depreſſed. By thus repeating the operation again and again, the air in the receiver is at length rarefied to ſuch a degree, that its denſity does not exceed the thin air remaining in the barrel when the piſton is raiſed: which done, the effect of the air-pump is at an end; the valve cannot now be opened, or if it could, no air would paſs it; there being a juſt equilibrium between the air on each ſide.

To judge of the degree of exhauſtion, there is added the gage-tube, *l l*, open at both ends, and about 34 inches long (*fig*. 33.), affixed to a wooden ruler, which is divided into inches and parts of an inch, from the bottom where it is even with the quickſilver in the baſon, *m*, and continued to the top, a little below the plate of the air pump, to 30 or 31 inches. Hence the air in the tube rarefying as faſt as that in the receiver, in proportion as the exhauſtion advances, the mercury will be raiſed by the preſſure of the column of external air, prevailing over that of the column of air included; till the column of air, and mercury together, become a balance to that of the external air. When the mercury is thus riſen to the ſame height as it ſtands in the barometer, which is indicated by the ſcale of inches added to the gage, the inſtrument is a juſt Torricellian tube; and the vacuum may be concluded to be as perfect as that in the upper end of the barometer. When the cock, *n*, is turned, ſo as to make a communication with the external air; this ruſhes in and the mercury in the gage immediately ſubſides into the baſon. See GAGE.

In eſtimating the gradual aſcent of the quickſilver in the gage, it is evident that, as we continue to pump, the mercury continues to aſcend; and that it approaches always more and more to the ſtandard altitude, or about 29½ inches, more or leſs according to the variety of ſeaſons. And it is eaſy to prove, that the defect of the height of the quickſilver in the gage from the ſtandard altitude is always proportionable to the quantity of air which remains in the receiver; that the altitude itſelf of the quickſilver in the gage is proportionable to the quantity of air which has been exhauſted from the receiver; and that the aſcent of the quickſilver, upon every turn of the pump, is proportionable to the quantity evacuated by each turn. Let it be conſidered, that the whole preſſure of the atmoſphere upon the ciſtern of the gage is equal to, and may be balanced by, a column of quickſilver of the ſtandard altitude; conſequently, when the quickſilver in the gage has not yet arrived to the ſtandard altitude, the defect muſt be ſupplied by ſome other equal force, and that force is the elaſtic power of the air remaining in the receiver; which communicating with the upper part of the gage, hinders the quickſilver from aſcending, as it would otherwiſe do, to the ſtandard altitude. The elaſticity of the air in the receiver is then equivalent to the weight of the deficient quickſilver; but the weight of this is proportionable to the ſpace it ſhould poſſeſs, or to the defect of the height of the quickſilver in the gage from the ſtandard height; therefore the elaſticity of the remaining air is alſo proportionable to the ſame defect. But the denſity of any portion of air is proportionable to its elaſticity, and the quantity in this caſe is proportionable to the denſity; and therefore the quantity of air remaining in the receiver is proportionable to the defect of the quickſilver in the gage from its ſtandard altitude.

Hence it follows, that the quantity of air which was at firſt in the receiver before you began to pump, is proportionable to the whole ſtandard altitude; and conſequently the difference of this air, which was at firſt in the receiver, and that which remains after any certain number of turns, that is, the quantity of air exhauſted, is proportionable to the difference of the ſtandard altitude and the before-mentioned defect, that is, to the altitude of the quickſilver in the gage after that number of turns. Hence again it appears, that the quantity of air exhauſted at every turn of the pump is proportionable to the aſcent of the quickſilver upon each turn. See Cotes's Hydroſt. and Pneum. Lectures, lect. 13. See GAGE.

There are ſeveral inconveniencies attending air-pumps of the common form, though much improved from what they uſed to be formerly, and many attempts have been made to remedy them. It is a well-known fact, that pumps merely ſerve to rarefy the air to a conſiderable degree, and that none of them can produce a complete exhauſtion; as the mercury in the gage is not raiſed by any of them to the height which it occupies in the Torricellian tube, when well purged of air. Few pumps will bring it within $\frac{1}{10}$th of an inch. Hauksbee's, fitted up according to his own inſtructions, will ſeldom bring it within $\frac{1}{4}$th; pumps with cocks of the beſt conſtruction, and in the moſt favourable circumſtances, will bring it within $\frac{1}{40}$th; but none with valves fitted up with wet leather, or to any part of which water or any volatile fluids have acceſs, will bring it nearer than $\frac{1}{4}$th. Before we proceed to give an abridged account of the improvements that have been made in air-pumps, we obſerve, that the air-pumps moſt commonly uſed are made either with braſs ſtop-cocks, or with valves of oil-ſkin or of leather, for preventing the return of the air into the receiver, out of which it had been exhauſted. Pumps with ſtop-cocks, when well made and newly put together, are generally found to rarefy the air to a greater degree than thoſe which are made with valves; but after having been uſed for ſome time, they become leſs accurate than thoſe with valves. But the valves are alſo imperfect; as the external air, preſſing upon that in the piſton, prevents its riſing, when the claſtic force of the air in the receiver, under exhauſtion, is much diminiſhed. Attempts have been made, particularly by the abbé Nollet and Mr. Graveſande, to perfect the conſtruction of cocks. In Graveſande's double-barrelled pump, the cocks at the bottom of the piſtons are turned by an apparatus that is moved by the handle of the pump: the piſton has no valve, and the rod is connected with it by a ſtirrup, as in a common pump. This rod has a cylindric part, which paſſes through the ſtirrup, and moves ſtiffly in it through the ſpace of about half an inch, between a ſhoulder above and a nut below. The ſtirrup ſupports a round plate, which has a ſhort ſquare tube, that ſits tight into the hole of a piece of cork, and which has alſo a ſquare ſhank, that goes into the ſquare tube. Between the plate and the cork is put a piece of thin leather, ſoaked in oil, and another is placed between the cork and the plate which forms the ſole of the ſtirrup. When the winch is turned to raiſe the piſton from the bottom of the barrel, the friction of the piſton againſt the barrel keeps it in its place, and the rod is drawn up through the ſtirrup. The wheel has thus liberty to turn about an inch; and this is ſufficient to turn the cock, ſo as to cut off the communication with the external air, and to open that with the receiver. When this is done, the continued motion ſerves to raiſe up the piſton to the top of the barrel. When the winch is turned in the oppoſite direction, the piſton remains fixed till the cock is turned, ſo as to ſhut the communication with the receiver; and open that with the external air. The cock has one perforation diametrically through it, and another in a perpendicular direction to this; and after reaching the centre, it paſſes along the axis of the cock, and communicates with the open air. By this communication, when it is opened, the air ruſhes in, and balances the preſſure on the upper ſide of the piſton in this barrel, ſo that the preſſure on the other muſt be counteracted by the perſon who works the pump. In order to obviate this inconvenience, Graveſande put a valve on the orifice of the cock, by tying over it a ſlip of wet bladder or oiled leather; and by means of this the piſton is preſſed down, as long as the air in the barrel is rarer than the outward air, juſt as if the valve was in the piſton itſelf. Graveſande, and alſo Muſchenbroek, extol the operation of this pump, as exceeding that of pumps with valves. But it is evident that no preciſe eſtimate of its performance can be obtained, whilſt the piſtons, valves, and leathers of the pump are prepared by ſteeping them in oil, and afterwards in a mixture of water and ſpirits of wine. With this preparation the gage could not be brought within $\frac{1}{4}$th of an inch of the barometer. Beſides, a conſiderable ſpace is left between the piſton and cock, from which the air is never expelled; and if this be made very ſmall, the pump muſt be worked very ſlowly; otherwiſe the air will not have time to diffuſe itſelf from the receiver into the barrel, eſpecially when the expelling force or the elaſticity of the air, towards the cloſe of the operation, is very ſmall. The rarefaction will likewiſe be retarded by the valve, which will not open till the air below the piſton is conſiderably denſer than the external air. The cocks in pumps of this kind are ſubject to become looſe by uſe, and to admit air: an inconvenience which might, indeed, be prevented by placing the barrels in a diſh filled with oil. For a figure and deſcription of Graveſande's pump, ſee Graveſande's Mathem. Elem. of Natural Philoſophy, by Deſaguliers, vol. ii. p. 14. &c. Theſe pumps, if they were ever uſed in England, have been long ſuperſeded by the cheaper and more ſimple contrivance of valves, formed by tying a ſtrip of bladder over a ſmall hole, through which the air is allowed to paſs in one direction only.

In the year 1750, the ingenious Mr. Smeaton directed his attention to the improvement of valve pumps. In conſidering the ſtructure of theſe pumps, he obſerved, that the principal cauſes of their imperfection are, partly, the difficulty of opening the valves at the bottom of the barrels, and, partly, the piſton's not fitting exactly, when put down to the bottom, which leaves a lodgment of air that is of bad effect. The firſt of theſe imperfections is owing to the ſmallneſs of the common valves, which are made of a piece of thin bladder ſtretched over a hole generally much leſs than $\frac{1}{10}$th of an inch in diameter, and to the adheſion of the bladder to the plate upon which it is ſpread, by reaſon of the oil or water with which it is moiſtened: as the rarefaction of the air in the receiver is continued by the operation of the pump, its ſpring becomes ſo weak, that it is not able to overcome the coheſion of the bladder to the plate, the weight of the bladder, and the reſiſtance occaſioned by its being ſtretched. The larger the hole is, over which the bladder is laid, a proportionably greater force is exerted upon it by the included air in order to lift it up; and yet the aperture of the hole cannot be made very large, becauſe the preſſure of the incumbent air would either burſt the valve, or ſo far force it down into the cavity as to prevent its lying flat and cloſe upon the plate. In order to avoid theſe inconveniences, inſtead of one hole, Mr. Smeaton makes uſe of ſeven, all of equal

size and shape, one being in the centre, and the other six round it, so that the valve is supported at proper distances by a kind of grating, formed by the solid parts between these holes, and resembling a honeycomb; and that the points of contact between the bladder and grating may be as few as possible, the holes are hexagonal, and the partitions are filed almost to an edge. The breadth of these hexagons is $\frac{1}{10}$ths of an inch, and consequently the surface nine times larger than common; and as the circumference is three times greater than that of the common valve, and the cohesion to be overcome is, in the first moment of the air's exerting its force, proportional to the circumference of the hole, the valve over any of these holes will be raised with three times more ease. Besides, the raising of the valve over the centre-hole is aided on all sides by those that are placed round it; and as they all contribute as much to raise the bladder over the centre hole, as the air immediately acting under it, the valve will be raised with double the ease already supposed, or with a sixth part of the force commonly necessary. After the bladder begins to rise, it will expose a greater surface to the air underneath, which will cause it to move more easily.

The other defect in the common construction would still hinder the rarefaction from being carried on beyond a certain degree. For as the piston does not fit so closely to the bottom of the barrel, as totally to exclude the air, this air, as the piston rises, will expand itself; and pressing upon the valves in proportion to its density, hinder the air within the receiver from coming out. Hence, if the vacancy were equal to the 150th part of the capacity of the whole barrel, no air could pass out of the receiver, when expanded 150 times, though the piston were constantly drawn to the top; because the air in the receiver would be in *equilibrio* with that in the barrel, when in its most expanded state. In order to obviate this inconvenience, Mr. Smeaton shut up the top of the barrel with a plate, having in the middle a collar of leathers, through which the cylindrical rod works that carries the piston. The external air is thus prevented from pressing upon the piston; but for the discharge of the air that passes from below through the valve of the piston, there is a valve applied to the plate at the top, which opens upwards. By this construction, when the piston is put down to the bottom of the cylinder, the air under it will evacuate itself so much the more, as the valve of the piston opens more easily, when pressed by the rarefied air above it, than when pressed by the whole weight of the atmosphere; and as the piston may be made to fit as nearly to the top of the cylinder as it can to the bottom, the air may be rarefied as much above the piston, as it could before have been in the receiver. Hence it follows, that the air may now be rarefied in the receiver in duplicate proportion of what it could be upon the common principle. By this construction, the pump, consisting of a single barrel, may be worked with more ease than the common pump with two barrels, because the pressure of the outward air is taken off by the upper plate; and when a considerable degree of rarefaction is desired, it will produce it more speedily.

Mr. Smeaton has also contrived a new gage, which measures the expansion with certainty, to much less than the 1000th part of the whole. It consists of a bulb of glass, in shape resembling a pear, and sufficient to hold about half a pound of quicksilver. It is open at one end, and the other is a tube hermetically sealed at top. A scale divided into parts of about $\frac{1}{10}$th of an inch each, and answering to a 1000th part of the whole capacity, is annexed to it. This gage, during the exhaustion of the receiver, is suspended in it by a slip-wire. When the pump is worked as much as is thought necessary, the gage is pushed down, till the open end is immerged in a cistern of quicksilver placed underneath. The air being then let in, the quicksilver will be driven into the gage, till the air remaining in it becomes of the same density with the external; and as the air always takes the highest place, the tube being uppermost, the expansion will be determined by the number of divisions occupied by the air at the top. See GAGE.

This ingenious artist has succeeded so well in his construction of the air-pump, as to be able to rarefy air about 1000 times; whereas the best of the common air-pumps, esteemed good in their kind, and in complete order, never rarefied it above 140 times. Mr. Smeaton's air-pump acts also as a condensing engine, by the very simple apparatus of turning a cock; see CONDENSER. This air-pump is thus easily made an universal engine, for shewing any effect arising from an alteration in the density or spring of the air; and with a little addition may be made to shew the experiments of the *air*-FOUNTAIN, AIR-*gun*, &c. Phil. Trans. vol. xlvii. p. 415—423.

A perspective view of the principal parts of this pump is exhibited in *Plate* VI. *Pneumatics*, *fig.* 45. A is the barrel, B the cistern, in which is included the cock, with several joints, which are covered with water to keep them air-tight; and a little cock to let the water out of the cistern is marked 6. C *c c* is the triangular handle of the key of the cock, which, by the marks on its arms, shews how it must be turned, that the pump may produce the effect desired. D H is the pipe of communication between the cock and the receiver. E is the pipe that communicates between the cock and the valve, on the upper plate of the barrel. F is the upper plate of the pump which contains the collar of leathers *d*, and V is the valve, which is covered by the piece *f*. G I is the syphon-gage, which is screwed on and off, and adapted to common purposes. It consists of a glass-tube hermetically sealed at *c*, and furnished with quicksilver in each leg, which, before the pump begins to work, lies level in the line *a b*; the space *b c* being filled with air of the common density. When the pump exhausts, the air in *b c* expands, and the quicksilver in the opposite leg rises, till it becomes a counterbalance to it. Its rise is shewn upon the scale I *e*, by which the expansion of the air in the receiver may be nearly estimated. When the pump condenses, the quicksilver rises in the other leg, and the degree may be nearly judged of by the contraction of the air in *b c*; marks being placed at $\frac{1}{2}$ and $\frac{1}{3}$ of the length of *b c* from *c*, which shew when the receiver contains double or treble its common quantity. K L is a screw-frame to hold down the receiver in condensing experiments, which takes off at pleasure, and is sufficient to hold down a receiver, the diameter of whose base is seven inches, when charged with a treble atmosphere; in which case it acts with a force of about 1200 pounds against the screw-frame. M is a screw that fastens a bolt, which slides up and down in that leg, by means of which the machine is made to stand fast on uneven ground. The structure, connection, and relative uses of the several parts of this pump will be further perceived in the following account of Smeaton's air-pump, constructed and improved by Mr. Nairne.

A perspective view of it appears in *Plate* VI. *Pneumatics*, *fig.* 46. A, A, are the two barrels of a simple double-barrelled air-pump; the tube *q q* conveys the air from the receiver placed in the pump-plate T, and the cock Q serves to cut off the communication between the receiver and the barrels, A, A, when the exhaustion is completed. In the front of the pedestal Z is a screw, serving to admit air into the barrels, that the valves may not be pressed after the cock Q is turned; the button *i* readmits air into the

receiver; the syphon-gage y is made in the usual manner; but the cisterns x, x, prevent the gages from being dirtied by the oil, on the readmission of the air. The large barrel C has a solid plunger, worked by the rod R, which passes through the collar of leathers u; for the construction of which, as well as the internal structure of the barrel C, see *fig.* 47.

This is a vertical section of the barrel, &c.; the top or cup U screws on to the screw u, and the cavity b is made conical; the holes e, e, are made just large enough to let the piston rod pass freely; the cavity b is filled with circular greased leathers, through the center of which a hole is made, that barely admits the piston rod to pass; these leathers are crouded into b, and three or four thicknesses of them are left above the surface, f; and consequently, when the cup U is screwed down, these leathers are forced into the smaller part of the conical hollow b; and therefore they bind as much or as little as is requisite on the piston rod. The head a is screwed with eight screws on the upper flaunch or part of the barrel C; the bottom B screws on the lower flaunch or lower end of C; the plug D is accurately ground into a conical hole in the bottom B and has the lever L standing at right angles. As the whole nicety of the exhaustion of this air-pump depends upon this part, it should be very particularly described. The lever L is represented as standing to the left hand; and the hole 2 with its valve 1 is seen in connection with the pipe P, and consequently with the receiver; see the horizontal section L D P. But if the lever L is brought towards the word "CLOSED," the hole 2 with its valve 1 has moved onwards towards D; no hole is opposite to the hole of P, and consequently all communication between the receiver and the inside of the barrel C is cut off; but upon moving the lever L more towards the right hand, the hole 3 having "NO VALVE" will be in connection with P, and consequently there will be a direct or uninterrupted passage between the receiver and the inside of the barrel C. Upon attentively inspecting the section, it will be perceived by the directions in which the valves open and close, and the position of the passages which are drilled through the thickness of the barrel, that the ascent or descent of the solid plunger N equally exhausts the pipe P, and consequently the receiver. It must be remarked, that the valves exhibited in the section are drawn like lids of boxes, with joints for the purpose of shewing in what direction they open; but in reality the valves are made of oiled silk; and as on the nice construction of these the good action of the pump much depends, the best mode of making them will be illustrated in the section, *fig.* A A, which shews the plug D, on which the valve is to be fixed. In the first place, a groove must be turned, of a convenient size, so as to leave a cylindrical knob F, whose diameter may be four or five eighths, or more, of an inch; the hole which the oiled silk valve is intended to cover, is made through the axis or center of this knob, as is shewn by the dotted lines H; the ring G is to fit nicely into the groove, and to be flush with the general surface of the brass; the surface of the knob F must be turned away about double the thickness of the oiled silk for the purpose of preserving the oiled silk from injury by the piston's striking it; a slip of oiled silk about the width of four times the diameter of the hole, which it is to cover, must be laid over the hole in the center of the knob F, and the ring G carefully put in its place and there fixed by two or three screws. *Fig.* B B shews the construction of the reservoir x x, (*fig.* 46.), for the purpose of keeping the gages clean. The end of the gage G, for instance, passes through the bottom of the reservoir x, and reaches nearly to the top; and a piece of metal, flat or like an inverted tea-saucer, is fixed to the top of x, *fig.* B B. The oil which comes from the pump through m is thrown on the back of the saucer, and running to its edges drops into the bottom part of the reservoir, and thus prevents any filth from getting into the tube G, *fig.* 46.

Having described the particular parts of this pump, we shall next explain the mode of working it, so as to obtain the greatest degree of exhaustion. A receiver well ground and made dry, with oil put upon its edge, is to be placed on the pump plate T, (*fig.* 46.), over the aperture of the pipe P; and the lever L is to be moved so as to stand under the word "VALVE." By working the piston of the cylinder C up and down, from the top to the bottom, the receiver becomes partly exhausted, and the mercury will rise from the cistern M up into the tube of the barometer gage G; the exhaustion must be continued till it will rise no higher; and turning the lever L under the word "CLOSED," the piston must be moved two or three times up and down; let it then be left at the bottom of the barrel C; move the lever L under the words "NO VALVE," and gently raise the piston to the top of the barrel. As there is now a direct communication between the receiver and the barrel C, without the intervention of a valve, the air will expand itself freely into the barrel, and the mercury of the gage will rise; keeping the piston at the top of the barrel, turn the lever again under the word "CLOSED," and repeat the operation as before; unscrew the receptacle for dirty oil O, and screw in its place the complete small exhausting syringe S; work this a few times, and repeat the operation with the barrel and the lever L as before, till the mercury will rise no higher in the gage.

By the process now described, the exhaustion has been made so perfect, that when an open cistern barometer, suspended in the room, has been on the rise, the mercury in the gage G has risen within $\frac{1}{100}$th of an inch as high.

The double-barrelled air-pump A A being placed on the same stand, and having a communication with the pump plate T, as well as the improved pump C, is intended for exhausting large receivers very expeditiously; as both pumps may be worked at the same time; and more especially for preventing the improved pump from being used for trifling experiments, or those where water is made use of. In the pump plate T are two holes, situated near each other, one communicating with the double-barrelled, and the other with the improved pump, and serving the purpose of cutting off the communication of either with the receiver at pleasure. Indeed, when the double-barelled pump is only used, the hole of the pipe P, leading to the barrel C, should always be carefully stopped to prevent moisture of any kind from getting into it.

Since the time of Mr. Smeaton the air-pump has received very material improvements; for which we are indebted to the Rev. Mr. Prince, of Salem, in North-America; and to Mr. Cuthbertson, late of Amsterdam, and since settled in London.

Mr. Smeaton's success in facilitating the opening of the valves, at the bottom of the barrel and in the piston, led Mr. Prince to conceive, that if these valves were entirely removed, and the remaining air in the barrel could be more perfectly expelled, the rarefaction might be carried still farther. Upon this plan he constructed his air-pump. He removed the lower valve, and opened the bottom of the barrel into a cistern on which it was placed, and which had a free communication with the receiver; for the valve on the upper plate, at the top of the barrel, constructed like Mr. Smeaton's, made it unnecessary that there should be any at the bottom, in order to rarefy the air in the receiver. The cistern was made deep enough to admit of the piston's descending into it below the bottom of the barrel. If the piston be solid, that is, without a valve, when it enters the

barrel and rises to the top-plate, which is made air tight with a collar of leathers, like Smeaton's, it forces out all the air above it; and as the air cannot return into the barrel on account of the valve in the top-plate, when the piston descends, there will be a vacuum between it and the plate; every thing being supposed perfect. But in working the pump, the piston is not allowed to descend entirely into the cistern so far as to leave the bottom of the barrel open; but it descends below a hole in the side of the barrel near the bottom, which opens a free communication between the barrel, cistern, and receiver. Through this hole the air rushes from the cistern into the exhausted barrel, when the piston has dropped below it; and by its next ascent this air is forced out as the other was before. If the capacity of the receiver, cistern, pipes, &c. below the bottom of the barrel, taken together, be equal to the capacity of the barrel, half the remaining air will be expelled by every stroke. But as the working of this pump with a solid piston would be laborious, on account of the resistance it would meet with in its descent from the air beneath, though it would be lessened by every stroke as the air became more rarefied, Mr. Prince pierced three holes in the piston at equal distances from each other, and by a circular piece of bladder, tied over the top of the piston, formed a kind of valves over the holes, which opened with sufficient ease to prevent any labour in working the pump, by allowing the air to pass through the piston in its descent. The escape of the air does not, however, depend upon a passage through the piston into the barrel; for when the air, weakened by rarefaction, cannot open this valve, it will still get into the barrel when the communication is opened by the hole at the bottom. This piston will therefore descend as easily as any other, nor will the valves impede the rarefaction. By this construction the valves, made to open with more ease by Mr. Smeaton, are rendered unnecessary for rarefying the air; and that at the bottom of the barrel is entirely removed; the valve on the top plate being the only one necessary in rarefying the air.

Having set aside the valves, which partly prevented the air from entering the barrel above the piston, Mr. Prince's next attempt was to expel the air more perfectly out of the barrel than Mr. Smeaton had done, by making a better vacuum between the piston and the top plate, so that more of the air might be allowed to expand itself into the barrel from the receiver. Mr. Prince also contrived to connect the valves on the top plate with the receiver occasionally by means of a pipe and cock, by the turning of which the machine might be made to exhaust or condense at pleasure. In order to remove the pressure of the atmosphere from the valve on the top plate, so that this valve might open as easily as the piston valve, he connected with the duct on the bottom piece, which conveys the air from the valves to the cock, a small pump of the same construction as the large one; having the barrel opening into the cistern, the piston rod, which is solid, moving through a collar of leathers, and a valve near the top, through which the air is forced into the atmosphere. This pump with one barrel is called the valve-pump; its chief use being to rarefy the air above the valves, or to remove the weight of the atmosphere from them. When this valve pump is used, the passage through the cock is shut up; and, therefore, instead of placing three ducts at equal distances round the cock in the manner of Mr. Smeaton's, Mr. Prince divided the whole into five equal parts, leaving the distance of one-fifth part between the ducts leading from the cistern and the valves to the cock, and two-fifths between each of these and the one leading from the cock to the receiver. By this adjustment, when the communication is open between the receiver and the valves for condensation, the other hole through the cock opens the cisterns to the atmosphere; but when the communication is made between the cisterns and the receiver for exhaustion, a solid part of the key comes against the duct leading to the valve, and shuts it up, and the air which is forced out of the barrel passes through the atmosphere into the valve-pump; for the valve of the small pump may be kept open while the great one is worked.

Upon this construction, the pump with two barrels may be made like the common pump, which cannot be conveniently done where the lower valve is retained. In this pump the pistons do not move the whole length of the barrels; an horizontal section being made in them a little more than half way from the bottom, where the top-plates are inserted. The pump is thus made more convenient and simple, as the head of it is brought down upon the top of the barrels in the same manner as in the common air-pump. The barrels also stand upon the same plane with the receiver plate, and this plane is raised high enough to admit the common gage of 32 or 33 inches to stand under it without inconvenience in working the pump: as the winch moves through a less portion of an arch at each stroke than it would do if the pistons moved through the whole length of the barrels.

A gage for measuring the degree of condensation having a free communication with the valves, cock, &c. is placed between the barrels in this pump; and the gage is so constructed that it will also serve to measure the rarefaction above the valves when the air is worked off by the valve-pump. It consists of a pedestal, the die of which is made of glass, which forms a cistern for the mercury, a hollow brass pillar, and glass tube hermetically sealed at one end, which moves up and down in the pillar through a collar of leathers. When the pump is used as a condenser, the degree of condensation is shewn by a scale marked on one edge of the pillar; when it is used as an exhauster, the degree of rarefaction of the air above the valves is shewn by a scale on the other edge of the pillar. This gage will also shew, when the valves have done playing, either with the weight of the atmosphere on them or taken off, in the manner which the author has described. The degree of condensation may be also measured by the number of strokes of the winch. For the purposes of great condensation, Mr. Prince has fitted a condenser of a smaller bore than the barrel of the great pump to the cistern of the valve-pump, to be screwed on occasionally. Or, without this condenser, the valve-pump may be adapted to the purpose by being made a little larger, and by having a plate made to screw into the bottom of the cylinder, with a valve on it opening into the cistern; a hole must be made to be opened on the same occasion near the top of the cylinder, to let air in below the piston when this is drawn up above it.

The common gage, which is generally placed under the receiver-plate, is placed in the front of this pump, that it may be seen by the person who works it, and that the plate may be left free for other uses. The plate is so fix-d to the pipe leading to the cock, that it may be taken off at pleasure, and used as a transferrer; and it may also serve for other purposes.

The head of this pump is made whole, except a small piece on the back, where the wheel is let in; and the wheel is freed from the piston-rods by pushing it into the back part of the head, and it is kept in its place by a button screwed into the socket of the axis behind. By this apparatus the piston-rods are dislodged from the wheel, and let down into the cisterns, when the pump is not used; and in these cisterns they may also have the advantage of being covered with oil. The principal joints of this pump are sunk into sockets, that

the leathers which close them may be covered with oil to prevent leaking. The lower part of the pump is fitted with drawers to contain the neceſſary apparatus.

A perſpective view of a double-barrelled pump, made by Mr. Jones, according to the conſtruction of Mr. Prince, may be ſeen in *Plate* vii. *Pneumatics*, *fig.* 48. A, A, are two braſs barrels in which the piſtons move; the barrels communicate with the receiver placed on the pump by means of the pipe B C, and canal D E; the rods of the piſtons are ſeen at F, G; each of theſe is connected with a rack or piece having teeth on one ſide. At I there is a wheel, whoſe teeth are laid hold of by thoſe of the rack; ſo that by turning the handle H the piſtons are alternately raiſed or depreſſed, and the air is exhauſted out of the receiver K L, the tube B C, and the canal D E, which communicate with one another. At the top of each barrel is a plate, on which is a box *m n*, containing a collar of leathers; through this the cylindrical part of the piſton rod moves, air-tight; *o o* is the place of the valve on the top plate, into which a pipe is ſoldered that conveys the air from the valves to the duct, paſſing under the valve-pump P, which is deſigned for preventing the preſſure of the atmoſphere from acting on the valve of the top plate. Q is the piſton rod of this pump, and R the handle by which it is worked. Y is a cock to cut off occaſionally the communication between the receiver and the working parts of the pump. At S is a ſcrew, which cloſes the orifice of the canal D E, by unſcrewing which the air may be admitted when required. Z is an oil-veſſel for receiving the oil driven over by the action of the pump; and there ſhould be always a ſmall quantity of oil in the cups of the boxes *m*, *n*, that hold the collar of leathers through which the piſton rods move; *a b c* is the barometer-gage; *d e* the box or ciſtern containing the mercury; and there is a divided box-ſcale affixed to the tube, for aſcertaining the riſe or fall of the mercury; a ſmall ivory tube encompaſſes the lower end of the glaſs tube, and floats upon the quickſilver in the ciſtern; the upper end of this is always to be brought to coincide with the lower diviſion of the box ſcale, by means of the ſcrew under the ciſtern; and when it thus coincides, the diviſions on the ſcale give the true diſtance from the ſurface of the mercury in the baſon. The key *f* ſerves for tightening or looſening the ſcrews of the pump. When either piſton is down, in the operation of this pump, there is a free communication from the receiver through the tubes and the canal to the part of the barrel above the piſton; when the piſton riſes, it forces out the air above it through the valve in the top plate; and as this valve prevents the air from returning into the barrel, when the piſton deſcends, a vacuum is formed between it and the under ſurface of the top plate; as ſoon, therefore, as the piſton has deſcended below the holes communicating, by the tubes and pipe, with the receiver, the air ruſhes into the exhauſted barrel; on the next aſcent of the piſton, this air is forced out as before. To prevent the piſton from meeting any reſiſtance in its deſcent, there is a valve in it through which the air paſſes as the piſton deſcends; but the air does not neceſſarily depend upon a paſſage through the piſton in order to get into the barrel. By theſe means the piſton deſcends as eaſily as in any other conſtruction, while the valve in it does not impede the rarefaction. The valve pump P is, as we have obſerved, uſed for taking off the preſſure of the atmoſphere from the valve on the top plate of the pump, and for forming a more perfect vacuum between this plate and the piſton, that nothing may prevent this inſtrument from exhauſting as far as its expanſive power will admit. The barometer gage *a b c*, ſerving to meaſure the exhauſtion of the receiver, conſiſts of a tube, divided by an annexed ſcale of inches and fractional parts of an inch, whoſe higher orifice communicates with the receiver, and the lower is immerſed in a ciſtern of mercury. Before any exhauſtion has taken place the mercury in the tube and ciſtern is upon the ſame level; and after any number of turns of the handle of the pump, the air in the tube and receiver is equally rareſied, and the mercury will aſcend in the tube till the weight of the column above the ſurface of that in the ciſtern, and elaſticity of the air in the receiver, taken together, be equivalent to the weight of the atmoſphere; and if the altitude of the column is equal to the ſtandard altitude, the vacuum in the receiver, and that above the mercury in the barometer, are the ſame. For an account of the ſyphon-gage, occaſionally ſubſtituted for the barometer gage, and the pear gage; ſee Gage.

In a contrivance, ſuggeſted by an ingenious workman of the late Mr. Adams, and annexed to the pumps conſtructed by Mr. Jones, one of the lower flexible oil-ſkins, or leather valves in the two barrels, is attached to a braſs ring, which is allowed an interval of motion of $\frac{1}{25}$th of an inch; a long wire is fixed to a bar over the diameter of the ring, which wire paſſes along the body of the piſton and rod through a collar of leathers in the piſton. By the friction of theſe leathers upon the rod, as they move up and down, the lower valve is occaſionally raiſed and depreſſed; and thus a communication is opened with the barrel and receiver, and of courſe the exhauſtion is carried to as great a degree as the nature of the air itſelf appears to admit. By a compariſon of the height of the mercury in a good barometer tube, Mr. Jones did not obſerve the $\frac{1}{40}$th of an inch difference between this and that of the barometer gage to the pump; and conſequently the rarefaction was about 1200 times; and hence he concludes that it was equal in power to that of Mr. Cuthbertſon or any pump whatever.

We ſhall now deſcribe more minutely the parts of which Mr. Prince's improved air-pump conſiſts. *Fig.* 49. *Plate* vii. repreſents a perpendicular ſection of one of the barrels, the two ciſterns, condenſing gage, &c.; where A B is the barrel, C D is the ciſtern on which it ſtands, *a a a a* the leathered joint, ſunk into a ſocket, and buried in oil; E F is the piſton, with the cylindrical rod paſſing through a collar of leathers, G G, in the box H I. K ſhews the place of the valve on the top plate K, covered by the croſs piece M M, into which is ſoldered the pipe O O, that conveys the air from the valves to the duct going under the valve pump, as may be ſeen in *fig.* 51.: *o* is part of the ſaid duct; *p* is the joint ſunk into a ſocket in the croſs piece P P, which connects the ciſterns, and has a duct through it leading to them. Into this duct open the ducts *q* and *r*, the firſt leading to the gage in front of the pump, and the other to the cock and receiver. The other barrel is left out of the figure, except Q, which is the top of it brought down out of its place for the purpoſe of ſhewing the top plate that ſhuts up the barrel, ſeparated from the box, which contains the collar of leathers. S is one of the holes in the plate over which the valve lies, and which is covered by R in the croſs piece. V V is the piſton ſhewing the valve open on the top, which is to prevent labour when the pump condenſes. W X is the ciſtern, in which is more diſtinctly ſeen the ſhoulder for the leather, which cloſes the point between this and the barrel, and alſo the ſocket in which the oil lies over the leather. Y Z is the condenſing gage, with the orifice of the tube raiſed above the ſurface of the quickſilver; *e e* is the collar of leathers, through which the glaſs tube moves; and *i* is a ſmall pipe coming up through the quickſilver to form a communication between the valves and the gage. In *fig.* 50. is ſeen the upper ſurface of the top

plate which closes the barrel, being soldered into it, shewing the place of the valves over the three small holes. *Fig.* 51 is a perpendicular section of the bottom-piece, pipes, valve-pump, cock, &c. at right angles with the other section, *fig.* 49. The button *o* is screwed here into the top instead of the gage. C D is the valve-pump and cistern, *e* the place of the valve, under the cup; E F the cock, shewing the duct through it leading to the atmosphere; G H the pipe leading from it to the stem of the receiver plate, in which is the cock I, to shut up the duct when the plate is used as a transferrer. K K is the plate; L a piece to shut up the hole, into which tubes, &c. are occasionally screwed to perform experiments without removing the plate. The dotted line at O shews the place of the screw which presses the plate against the pipe; P Q the pipe and common gage standing in front of the pump. *Fig.* 52 is a horizontal section of the cock, and pieces containing the ducts leading from it to the receiver, the cisterns and the valves on the top of the barrels; A B the duct, connecting the cisterns together; C D the duct leading from the cisterns to the cock; G H the duct leading from the cock through the pipe A B (*fig.* 51.) to the valves; D E the duct through the cock, which occasionally connects the two last mentioned ducts with the duct E F, leading from the cock to the receiver; I the duct in the cock leading to the atmosphere, which, when connected with the duct at D, lets the air into the cisterns and barrels for condensation; the other duct through the cock at the same time connecting H and E. This duct also, when connected with E, restores the equilibrium in the receiver. K L is part of the duct leading from the cisterns to the gage. The dotted circles shew the places of the pipe and valve-pump on the piece, and *r* the place where the air enters the valve-pump from the duct G H, and is thrown into the atmosphere when the pump exhausts. *Fig.* 53 shews the under surface of the boxes which contain the collars of leathers with the cross piece which connects them together, having a duct through it, as represented by the dotted line, through which the air passes from the valves into the pipe. This figure is chiefly designed to shew the places in which the valves play, as at I. American Transactions, vol. i. Boston, 1785. Nicholson's Journal, vol. i. p. 121—128. Adams's Lectures on Nat. and Exp. Philos. by Jones, vol. i. p. 51—54, p. 153.

The air-pump of Mr. Cuthbertson is so excellent in its structure, and so powerful in its effect, that it claims particular notice and description. A perspective view of it appears in *Plate* VIII. *Pneumatics*, *fig.* 56. Its two principal gages are screwed into their places; but these need not be used together, except in cases where the utmost exactness is required. In common experiments, either of them may be taken away, and a stop-screw put into its place. When the pear-gage is used, a small round plate, large enough for the receiver to stand upon, must first be screwed into a hole at A; but when this gage is not used, this hole must be closed with a stop-screw. When all these gages are used, and the receiver is exhausted, the stop-screw B, at the bottom of the pump, must be unscrewed, to admit the air into the receiver; but when the gages are not all used, the stop-screw at A, or either of the other two which are in the place of the gages, may be unscrewed for this purpose. In *fig.* 57, C D represents one of the barrels of the pump, F the collar of leathers, G a hollow cylindrical vessel to contain oil; R is also an oil-vessel, which receives the oil that is driven with the air through the hole *a a*, when the piston is drawn upwards; and when this is full, the oil is carried over with the air along the tube T, into the oil vessel G: *e e* is a wire which is driven upwards from the hole *a a*, by the passage of the air; and as soon as this has escaped, falls down again by its own weight, shuts up the hole, and prevents any air from returning by that way into the barrel; at *d d* are fixed two pieces of brass, to keep the wire *e e* in such a direction as may preserve the hole air-tight. H is a cylindrical wire, which carries the piston I, and is made hollow to receive a long wire, *q q*, that opens and closes the hole L, which forms the communication with the receiver standing on the plate; *m* is part of a pipe, one end of which is screwed into the wire *q q*, that opens and shuts the hole L; and upon the other end, O, is screwed a nut, which, stopping in the smaller part of the hole, prevents the wire from being lifted too high. This wire and screw are more clearly seen in *fig.* 58, and *fig.* 62: they slide through a collar of leathers, *r r*, *fig.* 58, and *fig.* 61, in the middle piece of the piston. *Figures* 60 and 61 are the two main parts which compose the piston; and when the pieces in *figures* 59 and 62 are added to it, the whole is represented by *fig.* 58. *Fig.* 61 is a piece of brass, turned in a conical form, with a shoulder or ledge at the bottom; a long female-screw is cut into it, about two thirds of its length: and the remaining part of the hole, in which there is no screw, is about the same diameter as the screw part, except a thin plate at the end, which is of a breadth exactly equal to the thickness of *q q*. That part of the inside of the conical piece of brass, in which no thread is cut, is filled with oiled leathers with holes in them, through which *q q* can slide air-tight; there is also a male-screw with a hole in it, which is fitted to *q q*, and serves to press down the leathers *r r*. In *fig.* 60, *a a a a* is the outside of the piston, the inside of which is turned exactly to fit the outside of *fig.* 61; *b b* are round leathers, about 60 in number; *c c* is a circular plate of brass, of the size of the leathers; and *d d* is a screw, which serves to press them down as tight as is necessary. The male screw, at the end of *fig.* 59, is made to fit the female screw in *fig.* 61. If *fig.* 62 be pushed into *fig.* 61, this into *fig.* 60, and *fig.* 59 screwed into the end of *fig.* 61, these will compose the whole piston, as represented by *fig.* 58. H, in *fig.* 57, represents the same part as H in *fig.* 58, and is that to which the rack is fixed. If this, therefore, be drawn upwards, it will make *fig.* 61 shut close into *fig.* 60, and drive out the air above it; and when it is pushed downwards, it will open as far as the shoulders *a a* (*fig.* 60.) will allow, and suffer the air to pass through. A A (*fig.* 63.) is the receiver plate; B B is a long square piece of glass, screwed to the undermost side of the plate, through which a hole is drilled, corresponding with that in the centre of the receiver plate, and with the three female screws *b b c*.

In order to conceive how the rarefaction of the air is effected, suppose the piston to be at the bottom of the barrel, and a receiver to stand upon the plate, the inside of the barrel, from the top of the piston to *a*, is full of air, and the piston shut: when drawn upwards, by the hollow cylindrical wire H, it will drive the air before it, through the hole *a a*, into the oil-vessel R, and out into the atmosphere by the tube T. The piston will then be at the top of the barrel at *a*, and the wire *q q* will stand nearly as it is represented in the figure, just raised from the tube L, and prevented rising higher by means of the nut *o*. While the piston is moved upwards, the air will expand in the receiver, and be driven along the bent tube *m*, into the inside of the barrel. Thus the barrel will be filled with air, which, as the piston rises, will be rarefied in proportion as the capacity of the receiver, pipes, and barrel, is to the capacity of the barrel alone. When the piston is moved downwards again by H, it will force the conical part, *fig.* 61, out of the hollow part, *fig* 60, as far as the shoulders *a a*; *fig.* 58

will rest upon *a a*, *fig.* 60, which will then be so far open as to permit the air to pass freely through it, while at the same time the end of *q q* is forced against the top of the hole, and closes it in order to prevent any air from returning into the receiver. Thus the piston, while moved downwards, suffers the air to pass out between the sides of *fig.* 60. and *fig.* 61, and when it is at the bottom of the barrel, will have the column of the air above it; and, consequently, when drawn upward, it will shut and drive out this air, and by opening the hole L, give a free passage to more air from the receiver. This process being continued, the air will be exhausted out of the receiver as far as its expansive power will permit: for in this machine there are no valves, as in the common air-pumps, to be forced open by the air in the receiver, which, when its elasticity is diminished, it becomes unable to affect; nor is there any thing to prevent the air from expanding to the greatest degree.

In using this machine for exhaustion, no directions are necessary besides those which relate to common pumps, nor is any peculiar care required to keep it in order, except that the oil-vessel, G, be always kept about half full of oil. When it has stood for a considerable time without being used, it will be proper to draw a table-spoonful or two of oil through it, by pouring it into the hole in the middle of the receiver plate, when the piston is at the bottom of the barrel; then, by moving the winch backward and forward to raise and depress the piston, the oil will be drawn through all the parts of the machine; and the superfluous part will be forced out through the tube T, into the oil-vessel G. Near the top of the cylindrical wire H, is a square hole, which is intended to let in some of the oil from the vessel G, that the oiled leathers, through which the wire *q q* slides, may always be duly supplied with it.

When the pump is required to condense, either at the time when it exhausts, or separately, the piece which contains the bent tube T, must be taken away, and *fig.* 64. put into its place, and fastened by the same screws. In the plate, *fig.* 64, is drawn as it is made for a double-barrelled pump; but for a single barrel, one piece is used, represented by *b a a*, the double piece being cut off at the dotted line *a a*. In this piece is a female screw, for receiving the end of a long brass tube; to which a bladder, if sufficient for the experiment, must be tied; or else a glass, properly confined for this purpose, must be screwed to it. Then the air, which is exhausted out of a receiver standing on the plate, will be forced into the bladder or glass connected with the brass tube. But if the pump be double-barrelled, the apparatus, as represented by *fig.* 64, must be used, and the long brass tube screwed into the female screw at C.

The two gages are represented in *fig.* 65. and *fig.* 66; the one is the syphon-gage, and the other the barometer or long gage. When these are used, *fig.* 65. must be screwed into the female screw, *c b*, or into that at the other end *c*, *fig.* 63.; and *fig.* 66 into the female screw *a b*, *fig.* 63.

If it be used as a single air-pump, either to exhaust or condense, the screw K, which fastens the rack to the cylindrical wire H, must be taken out; then turning the winch till this wire is depressed as low as possible, the machine will be rendered fit to exhaust as a single air-pump; and if it be required to condense, the directions already given with regard to the bent tube T, and *fig.* 68, must be observed.

Mr. Cuthbertson has, by a variety of experiments with this air-pump, shewn its great powers of exhaustion. With the double syphon gage, and also with the long gage, compared with an attached barometer, in which the mercury had been repeatedly boiled, the difference between the heights of the mercurial column proved to be no more than $\frac{1}{40}$th of an inch, the barometer standing at 30 inches, which gives an exhaustion of 1200 times. On some occasions, when the air was in a very dry state, he observed the difference to be as low as $\frac{1}{100}$th of an inch, which indicates more than double the rarefaction. See Description of an improved Air-pump, by John Cuthbertson, 8vo. London: for an abstract, Nicholson's Journal, vol. i. p. 128—130.

We shall close our account of the two pumps of Prince and Cuthbertson with the following judicious remarks of Mr. Nicholson (in his Journal, vol. i. p. 131.) on their respective merits and imperfections. "There is no provision to open the upper fixed valve of Prince's greater barrel, except the difference between the pressures of the elastic fluid on each side of the strip of bladder; and this may reasonably be inferred to limit the power of his small pump. In Cuthbertson's pump, the same valve is exposed to the action of the atmosphere, together with that of a column of oil in the oil-vessel. The mischief in either instrument is probably trifling; but in both, the valve might have been opened mechanically. If this were done, the small pump of Prince might perhaps be unnecessary in most states of the atmosphere. With regard to the lower valves, Cuthbertson, by an admirable display of talents as a workman, has insured their action. Prince, on the other hand, has, by the process of reasoning, so far improved the instrument, that no valves are wanted. In this respect, he has the advantage of simplicity and cheapness, with equal effect. The mechanical combination of Cuthbertson's pump reduces the operation to one simple act of the handle: but Prince's engine requires some manipulation with regard to the play of the small pump; though this might have been remedied by a more skilful disposition of the first mover."

"The most perfect scheme for an air-pump, taking advantage of the labours of these judicious operators, seems to be that in which two pistons of the construction of Prince should work in one barrel; one piston being fixed at the lower end of the rod, and the other at the middle. The lower piston must come clear out of the barrel when down, and work air-tight through a diaphragm at an equal distance from the effective ends of the barrel. In the diaphragm must be a metallic valve, of the form of Cuthbertson's lower-valve, but with a short tail beneath, that it may be mechanically opened when the piston comes up. Above the diaphragm must work the other piston, similar to the first; but as it cannot quit the barrel when down, a small portion of the barrel must be enlarged, just above the diaphragm, so that the leathers may be clear in that position. Lastly, the top of the barrel must be closed and fitted with a valve and oil-vessel, according to the excellent contrivance of Cuthbertson."

"If we suppose the workmanship of such a pump to leave the space between the diaphragm and lower piston, when up, equal to one-thousandth part of the space passed through by the stroke of that piston, the rarefaction produced by this part of the engine will in theory bear the same proportion to that of the external air; and the same supposition applied to the upper piston, would increase the effect one thousand times more: whence the rarefaction would be one million times. How far the practical effect might fall short of this from the imperfections of workmanship, or the nature of the air, which in high rarefactions, may not diffuse itself equally through the containing spaces, or from other yet unobserved circumstances, cannot be deduced from mere reasoning without experiment."

It is observed in the Encyclopædia Britannica, (vol. xv. p. 107.) that a construction of the air-pump, similar to that

of Mr. Cuthbertfon, was invented, and, in fact, executed, before the end of 1779, by Dr. Daniel Rutherford, afterwards profeffor of botany in the univerfity of Edinburgh. He made a drawing of a pump, having a conical metal valve in the bottom, furnifhed with a long flender wire, fliding in the infide of the pifton rod with a gentle friction, fufficient for lifting the valve, and fecured againft all chance of failure by a fpring at the top, which took hold of a notch in the infide of the pifton-rod, about a quarter of an inch from the lower end, fo as certainly to lift the valve during the laft quarter of an inch of the pifton's motion. He had executed a valve on this principle; but his thoughts were diverted from the further profecution of the bufinefs.

In Phil. Tranf. (vol. lxxiii. p. 435,) we have a defcription by Mr. Cavallo, of an air-pump contrived and executed by Meffrs. Haas and Hurter, inftrument-makers in London, in the conftruction of which thefe artifts have revived Guericke's method of opening the barrel-valve during the laft ftrokes of the pump, by an external force; of this pump Mr. Cavello fays, that when it had been long ufed, it had, in the courfe of fome experiments, rarefied 600 times.

The drawing and defcription of a new air-pump, acting by means of a quantity of oil in the barrel, and invented by James Sadler, Efq. have been publifhed by Mr. Nicholfon, in his Journal, vol. 1. p. 441, &c. He fays, that it poffeffes the defirable requifites of fimplicity, cheapnefs, and power; though at the fame time he very properly fuggefts, that the oil, in procefs of time, may become changed by the circulation, and lefs fit for the purpofe, and probably carry with it bubbles of air. He does not mention its practical effects.

A new air-pump, fimilar in its principle to thofe of Mr. Smeaton and Mr. Cuthbertfon, has lately been conftructed by the Rev. Mr. Little, of the county of Mayo in Ireland. The principal parts of this machine are one barrel and pifton, one ftop-cock, one valve, and two pipes of communication. It is of a portable fize, and fo contrived as to be confined in a very fmall fpace. The barrel is placed horizontally, and the rack, by which the pifton is moved, underneath the barrel; fo that the machine may be packed in a box two feet long, 18 inches wide, and feven in depth. It is adapted to the purpofes of a condenfing as well as of an exhaufting engine. As to the effects of this pump, the author informs us, that in feveral trials of exhauftion, in the months of July, Auguft, and September, 1795, the air being generally very dry, the rarefaction produced, as fhewn by the pear-gage, was, five times, between 3000 and 4000: the mercury in the barometer gage ftanding at the fame times always above $\frac{1}{100}$th part of an inch higher than it ftood in a ftandard barometer of a wider bore, which was filled with mercury made very hot and poured into a hot tube, and the mercury in the reduced barometer-gage funk below the level of the furrounding mercury. In the other nine trials, the rarefaction, as fhewn by the pear-gage, was from 9000 to 26000; when the barometer-gage ftood at $\frac{2\frac{1}{2}}{100}$ths of an inch higher than that in the ftandard barometer, and funk in the reduced barometer ftill lower than before beneath the ftagnant mercury. For a particular defcription and drawing of this inftrument, and a minute detail of its practical effects; fee Tranfactions of the Royal Irifh Academy, vol. vi. p. 319—391.

The *portable* or *table air-pump* differs principally in fize and the ftructure of the gage from the common air-pump defcribed at the beginning of this article. It has two brafs barrels, which are firmly retained in a perpendicular fituation to the fquare wooden table on which they reft by a tranfverfe beam, which is preffed upon them by fcrews at the top of two pillars. From the hole in the centre of the pump-plate, there is a perforation or canal in a brafs piece, to the fore part of the frame of the pump; and from this canal there is a perforation right-angular to the former, paffing to the centre of the bafis of each barrel. At each of thefe centres a valve is placed opening upwards to admit the air into the barrels. To each barrel a pifton is fo fitted that the air cannot pafs between it and the fides of the barrel. Each pifton has a valve opening upwards, that the air in the lower part of the barrel may efcape through them into the common air. They are alfo connected with a rack, and are raifed or depreffed by a handle, the lower part of which is fixed to the axis of a cog-wheel, whofe teeth lay hold of the rack. One pifton is raifed and the other is depreffed, by the fame turn of the handle. The operation of exhaufting is the fame as in the common pump. Two barrels are advantageous, becaufe they perform the work more fpeedily, and alfo becaufe the weight of the atmofphere, preffing upon the rifing pifton, is counterbalanced by the fame weight preffing upon the other pifton defcending.

Behind the large receiver upon the pump-plate, there is a fmall plate for fuftaining a fmall receiver. From the hole at the centre of this plate there is a canal communicating with that which paffes from the large receiver to the barrels. Under the receiver is a fmall bottle containing mercury, a fmall tube filled with mercury and freed from air, and inverted with the open end in the mercury; this is called the fhort barometer-gage. As the air is taken out of the receiver on this fmall plate, it is taken at the fame time from the larger one; and the defcent of the mercury in the tube will point out the degree of rarefaction in the receiver. The mercury, however, does not begin to defcend in this tube till near three-fourths of the air have been exhaufted; and the air is faid to be as many times rarer than the atmofphere, as the column of mercury fuftained in this tube is lefs than the height at which the mercury ftands, at that time, in a common barometer. The fyphon-gage, which is fometimes ufed, is a glafs tube, bent in the form of a fyphon, hermetically fealed at one end and open at the other. The longeft leg is four inches, each of which is divided on an adjoining fcale, into 20 equal parts. After confiderable exhauftion the gage begins to act; and whilft the mercury falls in one leg, it rifes in the other; and the quantity of air remaining will be determined by the difference of the height at which it ftands in both tubes. This gage is placed in the fame fituation with the fhort barometer-gage. See Gage.

The fmall fingle-barrelled pump has two plates, one for receivers, and the other for a fhort barometer-gage. Its principle is the fame with that of the air-pump juft defcribed; excepting that it has only one barrel, and that its pifton is merely worked by the hand. In general the fingle-barrelled pump is made only with one receiver-plate and a mahogany bafis, to fave expences, and with its fmall apparatus, to be packed in a portable mahogany cafe.

Air-pump, *laws of rarefaction in the receiver of it.*—1. For the proportion of air remaining at any time in the receiver, (fuppofing no vapour from moifture, &c.) we have the following general theorem.—"In a veffel exhaufted by the air-pump, the primitive or natural air contained therein, is to the air remaining, as the aggregate of the capacity of the veffel and of the pump, (*i. e.* the cylinder left vacant in an elevation of the pifton, with the pipe and other parts between the cylinder and the receiver) raifed to a power whofe exponent is equal to the number of ftrokes of the pifton, to the capacity of the veffel alone raifed to the fame power." M. Varignon gives an algebraical demon-

stration of this theorem, in the Memoires de l'Acad. Roy. an. 1693, p. 233, seq. Id. an. 1705, p. 397, seq.; but it may be also demonstrated pneumatically, thus:—Calling the air remaining after the first stroke, the *first residual*; that after the second, the *second residual*, &c. and remembering that the air in the receiver is of the same density as that in the cylinder, when the piston is raised; it is evident, that the quantity of air in the receiver, is to the quantity of air in the cylinder, pipe, &c. as the capacity of the receiver to that of the cylinder, and consequently, the aggregate of the air in the receiver and the cylinder, *i. e.* the whole primitive air, is to the air in the vessel alone, *i. e.* to the first residual air, as the aggregate of the capacity of the receiver and the cylinder, to the capacity of the receiver alone. After the same manner it may be proved, that the quantity of the first residual air, is to the second residual, as the aggregate of the capacity of the receiver and cylinder to the capacity of the vessel alone. And the same proportion does the second residual bear to the third, and so of the rest.

This may be illustrated by an example. Suppose the capacity of the receiver to be twice as great as the capacity of the cylinder or barrel, then will the capacity of the barrel be to that of the barrel and receiver together as one to three; and the quantity of air exhausted at each turn of the pump is to the quantity of air which was in the receiver immediately before that turn, in the same proportion. So that by the first stroke of the pump, a third part of the air in the receiver is taken away; by the second stroke a third part of the remaining air is taken away; by the third stroke a third part of the next remainder is exhausted; and so on continually; the quantity of air evacuated at each stroke decreasing in the same proportion with the quantity of air remaining in the receiver immediately before that stroke; for it is very evident that the third part, or any other determinate part of any quantity must be diminished in the same proportion with the whole quantity itself. And as the quantity of air in the receiver is by each stroke of the pump diminished in the proportion of the capacity of the receiver to the capacity of the barrel and receiver taken together; each remainder will therefore be always less than the preceding remainder in the same given ratio; or, in other words, these remainders will be in a geometrical progression continually decreasing. To recur to the preceding example; the quantity exhausted at the first turn was a third part of the air in the receiver, and therefore the remaining air will be two-thirds of the same; and for the like reason, the remainder after the second turn will be two-thirds of the foregoing remainder; and so on continually; the decrease being always made, in the same proportion of two to three; consequently the decreasing quantities themselves are in a geometrical progression. And as the quantities exhausted at every turn decrease in the same proportion with these remainders; therefore the quantities exhausted at every turn are also in a geometrical progression. Thus it appears, that the evacuations and the remainders do both decrease in the same geometrical progression. If the remainders decrease in a geometrical progression, it is plain that, by continuing the agitations of the pump, you may render them as small as you please; that is, you may approach as near as you please to a perfect vacuum; but you can never entirely take away the remainder.

From the above reasoning it appears, that the product of the primitive air into the first, second, third, fourth, &c. residuals, is to the product of the first residual into the second, third, fourth, fifth, &c. as the product of the capacity of the receiver and cylinder together, multiplied as often into itself as the number of strokes of the piston contains units, is to the factum arising from the capacity of the receiver alone, multiplied so often by itself; that is, as the power of the aggregate of the capacity of the receiver and cylinder together, whose exponent is the number of strokes of the piston, to the capacity of the vessel alone, raised to the same power. Consequently, the primitive air is to the last residual, in the ratio of those powers.

2. The number of strokes of the piston, together with the capacity of the receiver and cylinder with the wire, &c. being given; to find the ratio of the primitive air to the air remaining.

Subtract the logarithm of the capacity of the receiver, from that of the sum of the capacity of the receiver and the cylinder; then, the remainder being multiplied by the number of strokes of the piston, the product will be a logarithm, whose natural number shews how often the primitive air contains the remainder required.

Thus, if the capacity of the receiver be 460, that of the cylinder 580, and the number of strokes of the piston 6; the primitive air will be found to the remaining air as 133,5 to 1, or 1335 to 10.

For, suppose the capacity of the vessel $= v$, that of the cylinder and vessel together $= a$, the number of strokes of the piston $= n$, and the remaining air $= 1$. Since the primitive is to the remaining air as a^n to v^n, the primitive air will also be to the remaining air, as $a^n \div v^n$ to 1. Consequently, if the remaining air be 1, the logarithm of the primitive air is $\overline{\log. a - \log. v} \times n$.

3. The capacity of the receiver and the barrel being given; to find the number of strokes of the piston required to rarefy the air to a given degree.

Subtract the logarithm of the remaining air from the logarithm of the primitive air; and the logarithm of the capacity of the receiver, from that of the aggregate of the capacity of the receiver and cylinder; then, dividing the former difference by the latter, the quotient is the number of strokes required.

Let the primitive air be p, the remaining air r, and the other quantities as before: and we shall have $p : r :: a^n : v^n$; and the $\log. p - \log. r = n \times \overline{\log. a - \log. v}$; and $n = \log. p. - \log. r \div \log. a - \log. v$.

Thus, if the capacity of the cylinder be supposed 580, that of the receiver 460, and the primitive air to the remaining air, as 1335 to 10: the number of strokes required will be found to be 6.

4. The proportion of the primitive air to the remaining air, together with the capacity of the receiver and the number of strokes of the piston, being given; to find the capacity of the barrel.

Let the first-mentioned proportion be that of p to r; the capacity of the receiver, v, that of the barrel, x, and the number of strokes of the piston, n; then $p : r :: \overline{v+x}|^n : v^n$; and $\log. p - \log. r = n \times \log. \overline{v+x} - n \times \log. v$: consequently, $\log. v + \frac{\log. p. - \log. r}{n} = \log. \overline{v+x}$. Hence, find the logarithm of the capacity of the receiver and barrel, and from this the capacity itself, and subtracting that of the receiver, the capacity of the barrel will be known. For $p : r :: 1335 : 10$, $v = 460$, and $n = 6$: consequently, $\log. \overline{v+x} = 2.6627578 + \left(\frac{3.1256530 - 1.0000000}{6} =\right)$ $.3542755 = 3.0170333$, the log. of 1040. Consequently, $x = 1040 - 460 = 580$. See Wolf. Elem. Math. tom. ii. p. 289, &c. Cotes's Hyd. and Pneum. Lectures, lect. 13.

To the air-pump belongs a large apparatus of other veſſels, accommodated to various kinds of experiments.

Beſides the effects, and the phenomena of the air-pump, recounted under the articles VACUUM, AIR, &c. we may add ſome others, which, related at large, make the ſubſtance of Mr. Boyle's Phyſico-Mech. Exper.—As, that the flame of a candle *in vacuo* uſually goes out in a minute, though it ſometimes laſts two, but the wick thereof continues ignited after; and even emits a ſmoke, which aſcends upwards.—That a kindled charcoal is totally extinguiſhed in about five minutes, though in open air it remain alive half an hour; that it goes out by degrees, beginning from the top and the outſides.—That red-hot iron is not affected by the abſence of the air; and yet that ſulphur or gunpowder will not be lighted thereby, but only fuſed.—That a match, after lying ſeemingly extinct *in vacuo* a long time, revives again upon the re-admiſſion of the air.—That a flint and ſteel ſtrike ſparks of fire as copiouſly *in vacuo* as out of it; and that the ſparks move in all directions, upwards, downwards, &c. here as in the air.—That magnets and magnetic needles are the ſame *in vacuo* as in air.—That ſmoke in an exhauſted receiver, the luminary being extinct, gradually ſettles to the bottom in a darkiſh body, leaving the upper part clear and tranſparent; and that inclining the veſſel ſometimes on one ſide, and ſometimes another, the fume keeps its ſurface horizontal, after the nature of other fluids.—That the ſyphon does not run *in vacuo*.—That water freezes *in vacuo*.—That heat may be produced by attrition in the exhauſted receiver.—That camphor will not take fire *in vacuo;* and that gun-powder, though ſome grains of a heap be kindled by a burning-glaſs *in vacuo,* will not give fire to the contiguous grains.—That glow-worms loſe their light in proportion as the air is exhauſted, and at length become totally obſcure; but upon the re-admiſſion of air, preſently recover it all.—That electricity appears like the Aurora borealis.—That vipers and frogs ſwell much *in vacuo,* but will live an hour and half, or two hours; and though ſeemingly quite dead in that time, come to life again after being ſome hours in the air.—That ſnails ſurvive ten hours; and efts or ſlow-worms, two or three days; leeches five or ſix.—That fiſhes will riſe up to the top of water, placed under an exhauſted receiver, becauſe the air-bladder is expanded, and they are thus made ſpecifically lighter than water; but if the bladder breaks, they ſink down to the bottom, and riſe no more.—That animals who live in water will not die by exhauſting the air out of the receiver, unleſs they are kept for a conſiderable time *in vacuo.*—That oyſters will remain alive *in vacuo* 24 hours without harm.—That the heart of an eel taken out of the body, continues to beat *in vacuo* more nimbly than in air; and this for a good part of an hour.—That warm blood, milk, gall, &c. undergo a conſiderable intumeſcence and ebullition *in vacuo.*—That a mouſe, or other animal, may be brought, by degrees, to ſurvive longer in rarefied air, than naturally it does.—That air may retain its uſual preſſure, after it is become unfit for reſpiration.—And that ſilk-worms' eggs will hatch *in vacuo.*

Beſides the above-mentioned phenomena, many others are recited by different writers on this ſubject, and they may be found in the Philoſophical Tranſactions of various Academies and Societies, and in the works of Torricelli, Paſcal, Merſenne, Guericke, Schottus, Boyle, Hooke, Hauksbee, Duhamel, Mariotte, Hales, Muſchenbroek, Graveſande, Deſaguliers, Franklin, Cotes, Helſham, Martin, Ferguſon, Adams, &c. &c. We ſhall ſubjoin for the exerciſe and amuſement of our readers ſome farther experiments, arranged under diſtinct heads. For experiments that require peculiar accuracy, the receiver ſhould not be placed upon leather, either oiled or ſoaked in water; but the plate of the pump ſhould be made very dry, and the inſide of the receiver ſhould be dried and rubbed with a warm cloth. The receiver may then be ſet upon the plate, and hog's lard, either alone or mixed with oil, be ſmeared round its outward edge. After performing any experiments, the pump ſhould be cleared of any vapour that has been generated, by exhauſting a large receiver to as great a degree as poſſible; and the vapour that remained in the barrel and pipes will be diffuſed through the receiver; and if this be large, one exhauſtion will be ſufficient for clearing the pump. With ſmall receivers the operation ſhould be repeated two or three times. In ſome of the beſt pumps, the plate and edges of the receiver are ground ſo accurately as not to require any leathers; but as the plate is liable to be ſcratched by ſetting the receivers upon it, hog's lard or tallow ſpread upon their edges will be uſeful. This will prevent the edges from damaging the plate, and will not admit any vapour. When leathers are uſed for connecting the receiver with a pump plate, and for making the junction air-tight, they are previouſly ſoaked in water, oil, or a mixture of melted bees' wax and hog's lard. When experiments are performed that require the uſe of mercury, a ſmall pipe ſhould be ſcrewed into the hole of the pump plate, in order to prevent any of it, that may be accidentally ſpilt, from paſſing into the air-pipe and barrels; which would looſen the ſolder and corrode the braſs.

I. Experiments for ſhewing the weight and preſſure of the air.

1. Exhauſt of its air a copper ball, ſuch as C (*Plate* V. *Pneumatics*, (*fig.* 26.) the neck of which is furniſhed with a ſtop-cock and a ſcrew by means of which it may be fixed to the plate of an air-pump; ſuſpend it, when exhauſted, on the end B of one arm of a balance, A B, and lay upon it the ſmall weight *p*, which muſt be counterpoiſed by a weight P in the oppoſite ſcale of the balance. Turn the cock of the ball, and the air will ruſh in and render it ſo much heavier, that the weight *p* muſt be removed in order to reſtore the equilibrium. If the ball holds a gallon, it will thus be found that a gallon of air weighs about the ſixth part of an ounce. See WEIGHT of the AIR.

2. Place the ſmall receiver O (*fig.* 35.) over the hole of the pump plate, and upon exhauſting the air, the receiver will be fixed down to the plate by the preſſure on its outſide; and this preſſure will be equal to as many times 15 pounds as there are ſquare inches in that part of the plate which the receiver covers. By turning the cock of the pump and readmitting the air, the receiver will become looſe. In order to prove that the receiver O is held down by the preſſure of the air, ſuſpend it on the hook of the wire P P paſſing through the collar of leathers at the top of the receiver M, by which it is covered, and thus let it down on the plate of the pump; and when the air is exhauſted from both receivers, the large receiver M will be fixed to the plate by the preſſure of the external air; but the ſmall one O will be looſe and may be eaſily removed; on letting in the air, the leſſer O will be fixed down upon the plate and the other will be releaſed.

3. Place a ſmall braſs or glaſs veſſel A B (*fig.* 27.) which is open at both ends over the hole of the pump plate, and cover the top of it with the hand; which, when the air is exhauſted, will be preſſed down by the weight of the external air, ſo that it cannot be releaſed without difficulty till the air is readmitted.

4. Tie a piece of wet bladder, as *b* (*fig.* 28.) over the open top of the glaſs A; when it is dry, ſet the open end

A over the hole of the pump plate, and as you exhaust the air, the bladder will be pressed down and assume within the glass a concave figure, and at length it will break with a loud report. If a piece of flat glass be laid upon the top of this receiver, and joined to it by a rim of wet leather, the pressure of the outward air will break the glass, when the internal air is exhausted.

5. Immerse the neck *c d* of the hollow glass ball *e b* (*fig.* 29.) in the water of the phial *a a*; place it on the plate of the pump, and cover it and the hole of the plate with the receiver A; exhaust this receiver, and the air will escape by its spring from the ball *e b*, through the neck *d c*, rise in bubbles through the water, and pass off into the external air. When it has done bubbling, turn the cock of the pump, and the air that is admitted will by its pressure on the surface of the water force it up in a jet into the ball *e b*, and almost fill it; the small quantity of remaining air, which occupied the whole ball, and which is now reduced to a small space of condensation, preventing the water from filling the whole cavity of the ball. This experiment may be varied by screwing the end A of the brass pipe A B F (*fig.* 30.) into the hole of the pump plate, and placing, by means of wet leather, upon the plate *c d* a tall receiver G H close at the top, exhausting the receiver of its air and stopping the pipe by the cock *e*; when this is done remove the apparatus from the pump, set its end A in a bason of water, and open the pipe by turning the cock *e*; and the pressure of the air on the water will force it up through the pipe, so that it will ascend in a jet to the top of the receiver. See Fountain.

6. Set the jar D (*fig.* 31.) containing quicksilver, near the hole of the pump plate, and cover both with the tall open receiver A B. Into the plate C, placed upon the upper end of this receiver, introduce the open glass tube *g f*, immersed at its lower extremity in the quicksilver of the jar D, and screwed by a brass top annexed to it at *h* to the syringe H, which is itself screwed to the plate C. By the ring I draw up the piston of the syringe, and thus exhaust the tube of its air; and the quicksilver in the bason pressed by the undilated air of the receiver A B will ascend in the tube. That this ascent is owing to the pressure of the air, and not to what some have called suction, may be evinced by exhausting the receiver of its air, which will cause the quicksilver to descend into the jar, and by readmitting the air, which will raise it again in the tube, although the piston of the syringe be not moved. If the tube be about 32 or 33 inches high, the quicksilver will rise nearly as high in the tube as it stands at that time in the barometer. If the syringe has a small hole at *m*, and the piston be drawn up above that hole, the air will pass through it into the syringe and tube, and the quicksilver will immediately fall down into the jar.

7. Place the jar A (*fig.* 32.) with quicksilver in it on the pump plate, cover it with the receiver B, and push the open end of the glass tube *de* through the collar of leathers in the brass neck C, almost down to the quicksilver in the jar. Exhaust the receiver B of its air, and the tube *d e*, which is close at the top *f*, will at the same time be exhausted. When the receiver has been well exhausted, push the open end of the tube into the quicksilver of the jar; and though the tube be exhausted of its air, the quicksilver will not rise in it, because there is no pressure on the surface of that in the jar. But upon admitting the air into the receiver, the quicksilver will immediately rise and stand as high as it did in consequence of the action of the syringe in the preceding experiment.

These two last experiments not only exhibit the weight and pressure of the air, but they also shew that these are increased or diminished in proportion to the increase or decrease of the air's depth. See Barometer and Torricellian *Experiment*.

8. Join the two brass hemispheres A and B together (*fig.* 36.) by the interposition of a wet leather, with a hole in the middle of it; then screw the end D into the plate of the pump, and turn the cock E of the pipe, C D, communicating with the hemispheres; and having exhausted the air, turn the cock so as to stop the pipe. Having removed it from the pump, screw at the end D, the piece F *h*; and two strong men pulling at the handles *g* and *h* will find it difficult to separate the hemispheres; for if the diameter be four inches, they will cohere together with a force equal to 188 pounds, the area being equal to the square of the diameter multiplied by ,7854, and the pressure on every square inch being 15 pounds; *i. e.* 16 ×, 7854 × 15 = 188,496 pounds. If they be suspended by either of the rings on the hook P of the receiver M (*fig.* 35.), and the receiver be exhausted of its air, they will separate of themselves.

9. Set the square phial A (*fig.* 37.) upon the pump plate, and cover it with the wire cage B; then placing it under a close receiver, exhaust the receiver and the phial which has a small hole under a valve at *b* of their air; and the air upon its readmission into the receiver, being prevented from passing into the phial by the valve *b*, will break it into a number of pieces by its pressure. Quicksilver may be also forced into wood, and made to pass through it by the pressure of the air.

II. Experiments for shewing the elasticity or spring of the air.

1. Place a bladder, containing a small quantity of air and well tied up, under a receiver; and when the receiver is exhausted, the air will expand and fill the bladder so that it will appear as if it were blown with common air. Upon letting in the air, the bladder pressed by it will be reduced to its original flaccid state. This bladder put into a box under a weight of 20 or 30 pounds, and covered with a receiver, will, upon the exhaustion of the receiver, raise the weight by means of the spring of the internal air.

2. Take the glass ball (*fig.* 29.) which was filled with water, a small bubble of air at the top of it excepted, and having placed it with its neck downward into the empty jar *a a*, and covered it with a close receiver, exhaust the receiver of its air, and the air-bubble will expand itself, and by its elastic force protrude the water out of the ball into the jar. Or, screw the pipe A B (*fig.* 30.) into the pump plate, and place the tall receiver G H upon the plate *c d*; exhaust the receiver, and then remove the apparatus and screw it into the copper vessel C C (*fig.* 38.) half filled with water. Then turning the the cock *e* (*fig.* 30.) and the air confined in this vessel will by its spring force the water through the pipe A B, and cause it to form a jet into the exhausted receiver, equal to that which was produced by the pressure of the air in a former experiment; other circumstances being alike.

2. Let the balls annexed to the heads of the hollow glass images (*fig.* 39.) contain water sufficient to render them specifically heavier than water. Place them under a receiver and exhaust it; and the air in the balls will dilate, force part of the water out, and render the images lighter than water, so that they will ascend. On re-admitting the air, they will descend. Small apertures made in the feet of these images will vary the experiment, and answer the same purpose.

3. Animals that die in an exhausted receiver are evidently oppressed at first as with a great weight, then convulsed, and at last expire in apparent agony. Instead of repeating experiments of this kind, the effect of exhaustion is ascertained by what is usually, though improperly, called the lungs-glass. This consists of a bladder tied round a small tube which passes into a bottle, and sealed so tight, that the air cannot escape any way but through the tube. When this machine is put under a receiver and the air begins to be exhausted, the spring of that, which is contained in the bottle, and which cannot escape, compresses the bladder; and when air is again let in, the bladder expands; and these alternate motions of compression and dilatation have been supposed analogous to those of the lungs. See *fig.* 40.

4. Pour quicksilver into the bottle A (*fig.* 41.) and screw the brass collar *c*, of the tube B C, into the brass neck *b* of the bottle, and let the lower end of the tube be immersed into the quicksilver, so that the air above the quicksilver may be confined there. Cover this tube, which is open at the top, with the receiver G and large tube E F, fixed by brass collars to the receiver and close at the top. Exhaust the receiver and its tube; and the air will be thus exhausted out of the inner tube B C through its open top C; and then the air confined in the bottle A will, by its spring, force the quicksilver in the inner tube as it was raised in a former experiment by the pressure of the atmosphere; and thus it appears that the elasticity of the air is equivalent to its weight.

5. Screw the end C of the pipe C D (*fig.* 42.) into the hole of the pump plate, and open the communication between the three pipes E, F, and D C, and the hollow trunk A B, by turning the three cocks *d*, G and H. Cover the plates *g* and *h* with wet leathers, having holes in their middle, so as to communicate with the pipes; place the close receiver I upon the plate *g*; shut the pipe F, by turning the cock H; and exhaust the air out of the receiver I. Shut out the air by turning the cock *d*; remove the machine from the pump; screw it to the wooden stand L; and put the receiver K upon the plate *h*, on which it will be loose whilst it is full of air; but upon turning the cock H, and opening the communication between the pipes F and E, through the trunk A B, the air in K will, by its spring, pass from K to I, till it becomes of equal density in both receivers; and then they will be held down with equal force upon their respective plates by the pressure of the atmosphere, and the force with which K was held down will be divided between K and I. Thus it appears, that a force equal to half the elastic force of common air will act within the receivers against the whole pressure of the common air on their outsides. This instrument is called a double transferrer, and it serves to transfer the air from one vessel into another.

6. Fasten a cork in the square phial A (*fig.* 37.) with wax or cement; put it upon the pump plate, cover it with the wire cage B, and place a close receiver over the cage. Upon exhausting the receiver of its air, that which was enclosed within the phial will dilate itself, and having no counter pressure on the outside, will break the phial outwards by the force of its spring.

7. Place a shrivelled apple under a receiver, and as it is exhausted, the spring of the air within the apple will plump it out and cause the wrinkles to disappear; but upon readmitting the air, it will return to its shrivelled state.

8. Put a fresh egg, from the small end of which a little of the shell and film is removed, under the receiver; and when the air is pumped out, the small bubble of air contained between the shell and film at the larger end, will dilate itself, and protrude the contents of the egg into the receiver. If the egg be placed in a jar of water under the receiver, its surface will be covered with bubbles of air in the progress of exhaustion.

9. Warm beer put under a receiver, exhausted of its air, will discharge bubbles, which will rise to the surface, and at length give it the appearance of boiling.

10. A piece of dry wainscot or other wood, being put into warm water and covered with a receiver, will discharge air, as the receiver is exhausted, and exhibit bubbles of air, especially about its ends, because the pores lie lengthwise. A cubic inch of dry wainscot has so much air in it, that it will continue bubbling for half an hour together.

If a piece of wood be made to pass through a plate covering the top of a receiver, with one part exposed to the air and the other immersed in a jar of water under the receiver, and the thumb be put on the top of the wood whilst the pump is working, the air contained in the pores of the wood will rush in bubbles through the water; but if the thumb be taken off, a stream of air will flow in through the wood; and thus by alternately taking off the thumb and placing it on the wood, the influx of the air will be alternately admitted and interrupted. See Air and Elasticity *of the Air*.

III. Experiments for shewing the resistance of the air.

1. The machine (*fig.* 43.) consists of two mills, *a* and *b*, of equal weight, and moving independently and freely on their axes. Each mill has four thin vanes or sails, fixed in the axis; those of the mill *a* having their planes perpendicular to the axis, and those of the mill *b* having their planes parallel to it. When the mill *a* turns round in common air, it will suffer little resistance, because its sails cut the air with their thin edges; but the mill *b* is much resisted, because the broad sides of its sails move against the air, when it turns round. Each axle has a pin near the middle of the frame, which passes through the axle and projects a little on each side of it; upon these pins the slider *d* may be made to bear, and thus hinder the mills from going, when the strong spring *c* is set on bend against the opposite ends of the pins. Having set the machine upon the pump plate, draw up the slider *d* to the pins on one side, and set the spring *c* at bend upon the opposite ends of the pins; then push down the slider *d*, and the spring acting with equal strength on each mill will set them at work with equal forces and velocities; but the mill *a* will run much longer than *b*, because it meets with much less resistance. Draw up the slider again, and set the spring upon the pins as before; then cover the machine with the receiver M (*fig.* 35.) upon the pump plate; and having exhausted it, push down the wire P P, through the collar of leathers in the neck *q*, upon the slider, which disengaging it from the pins will allow the mills to turn round by the impulse of the spring; and as there is no air in the receiver that yields any sensible resistance, they will move for a longer time than in the open air, and when one stops, the other will stop also. Hence it appears, that the air resists moving bodies, and that equal bodies meet with different degrees of resistance, according as they present greater or less surfaces to the air, in the planes of their motions.

2. Put the guinea *a* and feather *b* (*fig.* 44.) upon the brass flap *c*; turn up the flap, and shut it into the notch *d*. Then putting a wet leather over the top of the tall receiver A B, which is open at both ends, cover it with the plate C, so that the tongs *e d* may hang within the receiver. Then having exhausted the receiver, draw up the wire *f*, and the tongs *e d* will be opened by a piece at its end, and the flap *c*

falling down, the guinea and feather will be obſerved to deſcend with equal velocities, and by looking ſteadily to the bottom of the receiver, to fall to the pump plate at the ſame inſtant. When air is in the receiver, the guinea will fall in an inſtant, and the feather will deſcend gently and by an indirect motion. This apparatus is ſometimes ſo conſtructed as to let three guineas with their feathers fall ſeparately at three different times, without taking it off or exhauſting the air afreſh. See Resistance *of the Air*.

IV. Miſcellaneous Experiments.

1. Screw the ſyringe H (*fig.* 31.) to a piece of lead, weighing at leaſt one pound; pull up the piſton, which will cauſe a vacuum in the ſyringe, and the air by its preſſure will drive back the lead upon it; raiſing it and counteracting its natural weight. But if the ſyringe and annexed weight be placed in an exhauſted receiver, they will fall upon the piſton by their natural gravity, and upon readmitting the air, they will be drove upward again, ſo that the piſton will be at the bottom of the ſyringe.

2. To a balance AB, *Plate* vii. *Pneumatics*, *fig.* 54. ſuſpend a weight of lead, and let it be in equilibrio with a piece of cork. Place this apparatus under a receiver and exhauſt the air, and the cork will preponderate; but let the air be admitted, and the equilibrium will be reſtored. As the air is a fluid, all bodies loſe as much of their weight in it as is equal to the weight of an equal bulk of the fluid; and as the cork is largeſt, it loſes more of its abſolute weight than the lead, and of courſe muſt be heavier in order to compenſate this greater loſs; but when the air is removed, all bodies gravitate according to their quantities of matter, and therefore the cork, which balanced the lead in air, will appear to be heavier *in vacuo*. A more elegant apparatus for this experiment, conſiſting of a light glaſs ball A, and a braſs weight B, is exhibited in *fig.* 55.

3. Set a clean receiver upon the plate of a pump, and when you begin to exhauſt it, hold a candle to the ſide of the receiver oppoſite to your eye, and ſeveral colours, reſembling a halo, will appear about the candle, which are occaſioned by the vapours that ariſe from the wet leathers and their refraction of the light.

4. Place a lighted candle under a tall receiver, and if it holds about a gallon, the candle will continue to burn about a minute; and its light will gradually decay and at length be extinguiſhed. The ſmoke of the candle will aſcend and form a kind of cloud at the top of the receiver; but upon exhauſting it, the ſmoke will fall down to the bottom; thus ſhewing, that ſmoke does not aſcend becauſe it is poſitively light, but becauſe it is lighter than air.

5. Let the pipe repreſented in *Plate* viii. *Pneumatics*, *fig.* 68. be annexed to the top of an open receiver, and the air be exhauſted; then place one end of the pipe in the middle of a charcoal fire, and open the cock; and the noxious air of the charcoal will paſs through the pipe into the receiver; remove the pipe from it, and let down a ſmall lighted wax taper into the receiver, and it will be immediately extinguiſhed. A mouſe or bird let down into the receiver will be killed by the air which it contains. If a candle be let down gently, it will purify the air as it deſcends.

6. By connecting the wire that paſſes through the collar of leathers of a receiver with the trigger of a piſtol lock, placed under it, exhauſting the air, and then drawing the trigger, the flint will ſtrike the ſteel and produce ſparks of fire, which will not be viſible as in the open air. Or, if two iron bullets be made red-hot, and one of them be under an exhauſted receiver, it will not appear luminous, like the other which remains in the open air.

7. Set a bell upon a cuſhion under a receiver on the pump plate; and ſhake the pump ſo as to make the clapper ſtrike againſt the bell, and the ſound will be diſtinctly heard; but exhauſt the receiver, and if the clapper be made to ſtrike with great force againſt the bell, it will make no audible ſound; hence it is inferred, that air is neceſſary for the propagation of ſound.

Air-shafts, among *Miners*, denote holes or ſhafts let down from the open air to meet the adits, and furniſh freſh air. The damps, want, and impurity of air, which occur, when adits are wrought 30 or 40 fathoms long, make it neceſſary to let down air-ſhafts, in order to give the air liberty to play through the whole work, and thus diſcharge bad vapours, and furniſh good air for reſpiration: the expence of which ſhafts, in regard of their vaſt depths, hardneſs of the rock, drawing of water, &c. ſometimes equals, nay exceeds, the ordinary charge of the whole adit.

Sir Robert Murray deſcribes a method, uſed in the coal-mines at Liege, of working mines without air-ſhafts. Phil. Tranſ. N° 5.

When the miners at Mendip have ſunk a groove, they will not be at the charge of an air-ſhaft, till they come at ore; and for the ſupply of air have boxes of elm exactly cloſed, of about ſix inches in the clear, by which they carry it down about twenty fathoms. They cut a trench at a little diſtance from the top of the groove, covering it with turf and rods diſpoſed to receive the pipe, which they contrive to come in ſide-ways to their groove, four feet from the top; which carries down the air to a great depth. When they come at ore, and need an air-ſhaft, they ſink it four or five fathoms diſtant, according to the convenience of the breadth, and of the ſame faſhion with the groove, to draw as well ore as air. Phil. Tranſ. N° 39. See Mining.

Air-threads *of ſpiders*. See Threads.

Air-trunk, a ſimple contrivance by Dr. Hales, for preventing the ſtagnation of putrid effluvia, and purifying the air in jails and cloſe rooms; which conſiſts of a ſquare trunk open at both ends, one of which is fixed in the cieling and the other is extended to a conſiderable height above the roof. The noxious effluvia, aſcending to the top of the room, eſcape by this trunk. Some of theſe have been nine and others ſix inches in the clear; but whatever be their diameter, their length ſhould be proportionable, in order to promote the aſcent of the vapour. As the preſſure of fluids, and conſequently of the air, correſponds to their perpendicular altitude, the longer theſe trunks are, ſo much the greater will be the difference between columns of air preſſing at the bottom and at the top; and of courſe ſo much the greater will be their effect. See Ventilator.

Air-vessel, in *Hydraulics*, is a name given to thoſe metalline cylinders, which are placed between the two forcing-pumps in the improved fire-*engines*. The water is injected by the action of the piſtons through two pipes, with valves, into this veſſel; the air previouſly contained in it will be compreſſed by the water, in proportion to the quantity admitted, and by its ſpring force the water into a pipe, which will diſcharge a conſtant and equal ſtream; whereas in the common ſquirting engine, the ſtream is diſcontinued between the ſeveral ſtrokes. Other water-engines are furniſhed with veſſels of this kind.

Alcohol

ALCOHOL, *ardent ſpirit, ſpirit of wine. Alcool, Eſprit de vin.* Fr. *Weingeiſt,* Germ. *Spirito ardente, ſpirito de vino. Acquarzente,* Italian. The term alcohol is applied exclusively by modern chemiſts, to the purely ſpirituous part of all liquors that have undergone the vinous fermentation. As this ſubſtance bears a very high importance, both as a chemical agent and in its various combinations, we ſhall beſtow upon it conſiderable attention.

Alcohol is in all caſes the product of the ſaccharine principle, and is formed by the ſucceſſive proceſſes of vinous fermentation and diſtillation. All fermented liquors, therefore, agree in theſe two points; the one, that a ſaccharine juice has been neceſſary to their production; and the other, that they are all capable of furniſhing an ardent ſpirit by diſtillation.

Various kinds of ardent ſpirits are known in commerce, ſuch as brandy, rum, arrack, malt-ſpirits, and the like; theſe differ from each other in colour, ſmell, taſte, and ſtrength; but the ſpirituous part, to which they owe their inflammability, their hot fiery taſte, and their intoxicating quality, is the ſame in each, and may be procured in its pureſt ſtate by a ſecond diſtillation, which is termed in technical language, *rectification*.

We ſhall refer the reader to the articles of FERMENTATION *(vinous)*, DISTILLATION, and the ſeveral ſpecies of diſtilled ſpirits, for an account of the progreſſive ſtages in the formation of alcohol; and we ſhall here take up the ſubject with the proceſs of rectification or the ſecond diſtillation, whereby alcohol is brought to that ſtate of purity in

in which its chemical properties are the most conspicuous.

Alcohol, as well as ardent spirits of different kinds, is procured most largely in this country from a fermented grain-liquor, prepared for the express purpose of distillation, from grain, melasses, &c.; but in the wine countries, the spirit is obtained from the distillation of wine; whence the synonimous term, *spirit of wine*. We shall only take the example of brandy, which is the product of the first distillation of wine, and mention the method by which alcohol is procured from it by rectification.

Brandy is a compound of alcohol, water, a colouring extractive matter, and a small quantity of oil. It is to the two last that it owes its peculiar flavour, smell, and appearance, whereby it is distinguished from other distilled spirits. The object of the process of rectification is to separate the first from the other ingredients, and this separation is effected upon the principle that alcohol is the most easily volatilized when a gentle heat is applied, and therefore appears in the first product of distillation, whilst the extractive matter and much of the water remain behind. It is more difficult, however, to get rid of the small portion of oil which brandy contains, as this is soluble in alcohol, and will rise with it in distillation, unless prevented by the means which will be presently mentioned.

The observations of M. Baumé, and his directions for the preparation of alcohol, are so judicious and accurate that we shall here mention them.

The following is the process given by this able chemist: "To procure rectified alcohol, put a quantity of brandy in the water bath of an alembic, and proceed to distillation. Set apart the first product of the distillation when it amounts to about a fourth part of the liquor put into the alembic. Then continue the process till about as much more is obtained, or till the liquor comes over white and milky. Then re-distil the latter product, and mix the first half which comes over with the first part of the former distillation, and continue to distil as long as any spirit comes over. This latter portion may be again distilled, and the first product mixed with the former first products, as before. After each distillation, there remains in the alembic a watery liquor which retains the smell of brandy, but is entirely deprived of inflammable spirit, and is thrown away as useless.

"Having thus procured all the spirit from the brandy, return all the reserved first products to the alembic, and distill with a gentle fire. When about half the liquor has come over, it should be kept apart as pure rectified alcohol; the remainder is to be distilled as long as it is inflammable, and may either be again rectified, or reserved for those purposes where a spirit of inferior strength is required."

The reason given by this judicious chemist for the above process is this: the spirit which first passes over in distillation is the purest, and contains the least portion of gross essential oil; the latter portion, on the other hand, is almost saturated with this oil, and the difference between the two is easily distinguishable when rubbed on the hands; the first product leaves no smell of brandy, but the last gives an odour like the breath of drunkards, who digest their food imperfectly. The quantity of oil, however, varies according to the nature of the brandy; that which is made from wine alone containing the least oil, but that which is procured from wine lees being so full of it as to leave a stratum of the oil swimming on the watery extractive liquor left in the alembic, after all the spirit has been distilled off.

M. Dubuisson remarks concerning this oil, that the Languedoc brandies contain much more of it than the Cogniac; and that after distilling a large quantity of the former, the head of the alembic was covered with expanded drops of the oil, which adhered to the vessel. When collected together, and quite cold, they became as stiff as suet, had a chesnut colour, a strong disagreeable taste, and a smell like turpentine.

Various additions have likewise been made to the impure spirit, in order to assist in the separation of this oil. The simplest, and one of the most efficacious is water. This, when added to the oily spirit, turns it milky (as is the case with any other solution of essential oil in alcohol), and by weakening the adhesion between the oil and the spirit, it enables the latter to rise in distillation, unmixed with the former. The chief inconvenience of this addition is, that it weakens the strength of the spirit so much as to require successive rectifications before it can be sufficiently deprived of its watery part.

Chalk, crumb of bread, bran, and other substances, are also added before distillation to the spirit, when oily and ill flavoured; and they all have a good effect in keeping down the matters which contaminate the alcohol, and render the distillation more effectual in purifying it.

Quicklime is still more efficacious, but it much lessens the product of alcohol, alters its nature in some degree, and makes it more penetrating. It would appear, however, that there are some kinds of wine in which the odorant particles are so intimately mixed with the spirituous part, that it is scarcely possible to separate them by simple distillation, however cautiously and skilfully conducted.

The common still with the worm-tube and refrigeratory, is very well calculated for the rectification of spirits, only allowance must be made for the readiness with which ardent spirit, when heated, assumes the state of vapour, and the very great expansion which it then undergoes.

Alcohol, freed from all foreign ingredients but water, and already of considerable strength, may be brought to the specific gravity of 0.825, at the temperature of 60°, by a single distillation, where the heat is moderate and applied very gradually, and the condensation slow. When about a third or half of the spirit is distilled over, the strength of the succeeding portion is diminished, the specific gravity increases, and it becomes more watery, and therefore the first product should be kept apart. This cannot be rendered stronger by any repetition of simple distillation, but it may be still further dephlegmated by means which will be mentioned hereafter.

We shall now proceed to the properties of alcohol.

Alcohol is a colourless transparent liquor, appearing to the eye like pure water. It possesses a peculiar penetrating smell, distinct from the proper odour of the distilled spirit from which it has been procured. To the taste it is excessively hot and burning, but without any peculiar flavour. From its great lightness and mobility, the bubbles which are formed on shaking it subside almost instantaneously, and this is one method of judging of its purity. Alcohol is very easily volatilized by the heat of the hand, it even begins to be converted into a very expansible vapour at the temperature of 55° Fahr. and the quickness of evaporation always produces a considerable cold. It boils at about 165°, and the vapours when condensed return unaltered to their former state. It has never been frozen by any cold, natural or artificial, and hence its use in thermometers to measure very low temperatures.

Alcohol takes fire very readily on the application of any lighted body, the speedier in proportion to its purity. It burns with a pale flame, white in the centre and blue at the edges; this gives but a small degree of heat, and is so faint as to be scarcely visible in bright day-light. It burns with-

out any ſmoke or vapour, and if ſtrong, leaves no reſiduum; but if weak, it is extinguiſhed ſpontaneouſly, and the watery part remains behind.

Alcohol mixes with water in every proportion. Heat is extricated during the mixture, which is ſenſible to the hand, even in ſmall quantities. At the ſame time there is a mutual penetration of parts, ſo that the bulk of the two liquors, when mixed, is leſs than when ſeparate. Conſequently the ſpecific gravity of the mixture is greater than the mean ſpecific gravity of the two liquors taken apart. The alcohol may be again for the moſt part ſeparated from the water by diſtillation with a gentle heat. See GRAVITY *(ſpecific.)*

Owing to the great affinity which ſubſiſts between water and alcohol, this latter has the power of precipitating from their ſolution various ſalts diſſolved in water. Thus, if ſome ſtrong alcohol be added to a ſaturated ſolution of Glauber's ſalt in water, a coagulum is immediately produced, conſiſting of the ſalt ſeparated from the water in a very divided form, whilſt the alcohol and water form a chemical union. This precipitation, however, only takes place in ſolutions of thoſe ſalts which are inſoluble in alcohol. This circumſtance has been very ingeniouſly applied to the analyſis of various ſaline ſolutions, and eſpecially to the examination of mineral waters. The power of precipitating ſome of theſe ſalts extends to very dilute ſolutions. Mr. Kirwan, in his valuable work on mineral waters, has found by experiment that ſelenite may be completely precipitated from water which contains only one-thouſandth of its weight of this earthy ſalt, by any alcohol whoſe ſpecific gravity is below 0.850. For further particulars on this ſubject, we muſt refer the reader to the article; WATERS *(Mineral, analyſis of)*.

Alcohol is capable of uniting with a great number of ſubſtances, a circumſtance which renders its uſe very extenſive in a variety of chemical proceſſes and in analyſis. Theſe we ſhall enumerate.

Some of the weaker acids, ſuch as the boracic and tartareous, are ſoluble in alcohol without any apparent decompoſition, and may be again recovered by evaporating the ſpirit. The ſtronger acids, however, exerciſe a very powerful action on alcohol, and produce ſeveral very curious and important compounds, particularly that ſingular liquor called ETHER. See the articles ETHER, OIL OF WINE, and OLEFIANT GAS.

All the alkalies, when pure, may be diſſolved in alcohol, but the fixed alkalies, when combined with carbonic acid, are not ſoluble in this menſtruum. This affords a very convenient method of procuring the cauſtic fixed alkalies in a ſtate of purity, and by proper management they may be made to cryſtallize from their ſpirituous ſolution. The colour of a ſolution of alkali in alcohol is always ſomewhat red, however pure the alkali be, which is owing to a partial decompoſition of the ſpirit. See the articles POTASH and TINCTURE of SALT OF TARTAR.

Several of the neutral, earthy, and metallic ſalts, are ſoluble in alcohol. It is of ſome importance in chemical analyſis to aſcertain the degree of ſolubility of theſe ſalts, and many experiments have been made for this purpoſe.

The firſt of any importance are thoſe of M. Macquer. He employed a ſpirit rectified ſo far, that a phial holding a Paris ounce of diſtilled water, at the temperature of 45° Fahr. would contain ſix gros and fifty-four grains of the ſpirit. The ſalts which he employed were previouſly dried with care, ſo as to expel their water of cryſtallization. He poured into a matraſs upon each of the ſalts half an ounce of the ſpirit, and ſet the veſſel in a hot ſand-bath. When the ſpirit began to boil, he filtrated it while hot, and then left it to cool. He then evaporated the ſpirit, and weighed the ſaline reſiduums; and from theſe he inferred the quantity of ſalt which the ſpirit had diſſolved.

This method, however, cannot be conſidered as accurate, as ſome of the ſpirit muſt have evaporated during boiling, and ſome of the ſalt muſt have been depoſited in the pores of the filter. Neither would the errors produced in this way be uniform, ſince it appears that ſome ſalts are, in a greater proportion than others, more ſoluble in hot than in cold ſpirt.

Wenzel alſo publiſhed a ſeries of experiments, in 1777, on this ſubject. He varied the heat which he employed, according to the ſolubility of the ſalt.

He has, however, been guilty of a great omiſſion in not mentioning the ſpecific gravity of the alcohol which he uſed, but it may be ſuppoſed to be nearly the ſame as that of Macquer.

Laſtly, Mr. Kirwan, with that accuracy for which he is ſo juſtly diſtinguiſhed, has given in his treatiſe on mineral waters, a table of the ſolubility of certain ſalts, in which alcohol of different denſities is employed, and the temperature properly noticed.

Our readers will find the reſults of all the above-mentioned experiments in the following Table.

TABLE of the Solubility of SALTS in ALCOHOL.

Salts employed, all deprived of their water of cryſtallization.	MACQUER. Soluble in 288 grs. of Alcohol, of about 0.84 ſp.gr.	WENZEL. Soluble in 240 grs. of Alcohol, of about 0.84 ſp.gr.	KIRWAN. Soluble in 100 grs. of Alcohol, of different ſpecific gravity.—Heat, from 50° to 70°.				
	Boiling heat uſed.	Heat various, as ſpecified.	Sp. Gr. 0.9	Sp. Gr. 0.872	Sp. Gr. 0.848	Sp. Gr. 0.834.	Sp. Gr. 0.817
	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.
Nitrated Potaſh	4	5 boiling heat	2.76	1.	0	0	0
——— Soda	15	23 ditto	10.5	6.	—	0.38	0
——— Ammonia	108	214 ditto					
——— Lime	288						
——— Alumine	—	240 at 54°					
——— Magneſia	—	694 boiling					
——— Silver	84	100 ditto					
——— Iron	4	partly decompoſed.					
——— Copper	48	240 at 54°					
——— Zinc	—	decompoſed.					
——— Cobalt	—	240 at 54°					
——— Biſmuth	—	partly decompoſed.					
Muriated Potaſh	5	5 boiling	4.62	1.66	—	0.38	0
——— Soda	0	0	5.8	3.67	—	0.5	—
——— Ammonia	24	17 boiling	6.5	4.75	—	1.5	—
——— Lime	288	240 ditto					
——— Alumine	—	240 at 54°					
——— Magneſia (dried at 120° by Kirwan.)	—	1313 boiling	21.25	—	23.75	36.25	50.
——— Barytes	—	—	1.	—	0.29	0.185	0.09
Ditto, ditto, cryſtallized	—	—	1.56	—	0.43	0.32	0.06
Muriated Iron	36	240 boiling					
——— Copper	48	240 ditto					
——— Zinc	—	240 at 54°					
Corroſive Sublimate.	204	212 boiling					
Acetited Soda	—	112 ditto					
——— Lime	—	—	2.4	—	4.12	4.75	4.88
——— Lead	—	240 at 113°					
——— Copper	—	18 boiling					
Arſeniated Potaſh	—	9 ditto					
——— Soda	—	4 ditto					
Oxalic Acidulum	—	7 ditto					

On examining the comparative reſults given in the above Table, we cannot conſider them as very ſatisfactory, and in ſome inſtances we perceive ſo ſtriking a difference in the reſults, that it muſt depend on ſome more extenſive cauſe than mere caſual error. Probably the degree and continuance of heat employed, in drying the ſalt and expelling its water of cryſtallization, muſt have differed conſiderably in the reſpective experiments. It would be uſeleſs to attempt to explain the cauſe of difference in all the reſults, but this ſhews the great neceſſity of attending minutely to every particular in ſuch experiments.

The moſt important of the ſalts inſoluble in highly rectified alcohol are the following—all the ſulphats, both of the alkalies, earths and metals; ſome of the nitrated metals; ſome of the muriated metals; and the carbonated fixed alkalies.

A peculiar colour is perceived in the flame of ſome of theſe ſolutions in alcohol when ſet on fire. The ſolution of nitre gives a pale yellow flame, that of boracic acid is a faint green, all the ſolutions of copper burn with a beautiful bright green, and thoſe of nitrated or muriated ſtrontian ſhine with a deep blood red.

Ammonia, both pure and carbonated, diſſolves readily in alcohol. They are generally united by means of diſtillation, a moderate heat being ſufficient to volatilize each. Theſe combinations are principally employed in pharmacy.

Alcohol will readily unite with the carbonic acid gas, and will take up full its own bulk of it at a medium tem-

perature.—The gas, however, appears to have little or no action on the spirit, since it is expelled from it by heat unaltered.

Neither metals, nor metallic oxyds, nor metallic acids, appear to be in any degree soluble in alcohol.

Sulphur will not contract any union with alcohol by simple digestion either cold or hot; but when they are both reduced to the form of vapour, and then mixed, a true solution is effected, and the result is a very pungent spirit with a strong odour of liver of sulphur, and which becomes milky and deposits the sulphur on dilution with water.

Ardent spirit acts in a slight degree on PHOSPHORUS, and dissolves so much of this inflammable substance as to become slightly luminous in the dark when the solution is dropped into water.

None of the pure earths are soluble in alcohol, and this latter has the power of precipitating lime, barytes, and strontian, from their watery solutions.

It is on the chemical substances belonging to the vegetable kingdom that alcohol exerts its most powerful action as a solvent, and herein consists its very extensive use in pharmacy, in preparing liquors for the table, in some of the arts, and in a very important part of chemical analysis.

Most of the acids belonging to the vegetable kingdom are highly soluble in ardent spirit, such as the tartareous, the citric, the oxalic, and the gallic. In procuring the latter from the gall-nut, alcohol furnishes us with a very elegant and commodious method of separating the acid from the mucilaginous extractive matter with which it is naturally mixed.

The acetous acid, when of the usual strength, simply mixes with alcohol, without producing any decomposition, but chemists have succeeded in forming an acetic ETHER, by employing the acid in its most concentrated state.

Alcohol will readily dissolve SUGAR. Wenzel estimates the quantity at about one-fifth of the spirit. In all the sweet native vegetable juices, such as the sap of the sugar-cane and the maple, or the expressed liquor from the parsnip and beet root, the sugar is mixed with a large quantity of a mucilage very little soluble in alcohol. This furnishes a ready method for separating the purely saccharine part, a method which is much employed in the analysis of various vegetables, for the purpose of ascertaining the comparative quantity of sugar which they may be expected to yield to the manufacturer. The solution, when left to spontaneous evaporation, yields minute crystals of sugar, which are at first brown, and require a further purification.

Ardent spirit is an excellent solvent for essential oils, and in general, for the most odorous and inflammable of the vegetable productions. In the essential oil of a plant resides the Spiritus Rector, or the AROMA, that which gives the exquisite perfume to the rose or jessamine. When these odoriferous plants are distilled with alcohol, it rises strongly impregnated with their scent and flavour, and as it takes up no colouring matter it remains perfectly clear as before. Thus, the common lavender water is alcohol distilled off the lavender plant, and holding in solution the essential oil in which the scent resides. The *Distilled* SPIRITS in pharmacy, are similar preparations of alcohol, containing the flavour of spices, aromatics, or other substances with which it has been distilled. (See OILS ESSENTIAL).

All the RESINS are highly soluble in alcohol, but scarcely, if at all, in water. These solutions have the peculiar colour, and acrid taste of the resin which they contain. An addition of water renders them all turbid, and from the pure resinous solutions it precipitates almost the whole of the dissolved contents in the form of thick flakes. The solution of guaiacum affords an example of this.

The GUM RESINS, which are natural mixtures of gum and resin, yield their resinous part to pure alcohol and but little of their gum; water on the contrary dissolves the gum and leaves the resin; but a mixture of alcohol and water will hold both the ingredients in solution. These preparations are called TINCTURES in pharmacy, and they are of considerable use in containing within a small bulk, the medicinal virtues of larger quantities of the ingredients employed.

Artificial resins, or *Resinous* EXTRACTS, are also made by evaporating to dryness solutions of the resinous parts of several vegetables in alcohol.

CAMPHOR is readily and largely soluble in ardent spirit. This solution, when saturated, will let fall almost the whole of the camphor on the addition of water. Camphor also remarkably assists the solution of the resins.

Solutions of resinous substances in alcohol form the basis of the spirit VARNISHES, which when applied in thin layers over any substance, soon dry from the evaporation of the spirit, whilst the resin remains behind furnishing a smooth thin coating to the surface which they are intended to protect.

The fixed oils, when in their simple state, are entirely insoluble in alcohol, but they may be rendered soluble in this menstruum, either when they have been converted into drying oils by the action of metallic oxyds, or when they are united with alkalies in the form of SOAP. A solution of fine soap in alcohol is perfectly colourless and transparent, and will bear dilution with water without becoming turbid. It is employed in medicine as an external application, and is also a good reagent in the analysis of mineral waters to discover the presence of earthy salts. These decompose the soap by double affinity, and produce curdling.

The effect of alcohol on animal substances bears a considerable resemblance to its operation on the vegetable kingdom.

Muscular fibre and the coagulum of blood are not soluble in this menstruum, but are rendered by it hard, contracted, and incapable of putrefaction.

Albumen is equally insoluble in alcohol and is coagulated by it, probably owing to abstraction of the water which held it in solution. Milk is speedily curdled by ardent spirit of every kind.

Alcohol will dissolve WAX, SPERMACETI, BILIARY CALCULI, and the strong scented animal resins or resinous extracts, such as MUSK and AMBERGRIS. This menstruum, however, does not appear to be so extensively applicable to the analysis of animal substances as of those from the vegetable kingdom.

We have already mentioned that alcohol well rectified may be brought to the specific gravity of 0.825 (at 60° temperature) by a simple distillation, where the process is slowly and carefully conducted, and when only the first third, or half of the spirit which comes over is taken. Chemists have, however, been able to bring it to a higher state of dephlegmation, and consequently a less specific gravity. This is done by adding to the spirit in the alembic or still a quantity of a salt which is itself insoluble in alcohol, and which has such a greedy attraction for water as to be able to separate it from the spirit. Boerhaave recommends for this purpose common salt, hot, dry, and decrepitated. He allows the salt and the spirit to stand together for twelve hours, and then to be heated in a water-bath so as to distil off the spirit

by a very gentle warmth. The salt is left moist in the still, and contains much of the water of the spirit employed. Some recommend burnt alum in the room of salt, but the best addition is very dry, hot, carbonated alkali. A highly dephlegmated alcohol may be prepared in this method without the intermediate process of distillation, only then the spirit will be of a reddish colour, and will contain that small portion of caustic alkali which is always mixed with common carbonated potash, and which is soluble in ardent spirit. The following is Boerhaave's process: "Take a clean glass "body containing common spirit of wine, and add thereto "one-third of its weight of pure and dry potash, (carbo-"nated potash), which immediately falls to the bottom. "Shake the glass, and the salt directly grows moist and "begins to dissolve at the bottom, whilst a red thin liquor "floats above it; the more the vessel is shaken, the more "liquid is the lower part of the salt, and the more distinctly "separated from the upper liquor, nor is it ever possible to "mix them together, but upon resting they will immediately "separate into two liquors."

This process may be continued, he adds, by decanting carefully the upper of the two liquors, (which is the alcohol reddened by a little caustic alkali that it holds dissolved) and adding to it more carbonated alkali, till the portion last added will no longer become wet on shaking, a sign that the alcohol is as fully deprived of water as it is capable of being made by means of alkali. As a proof of the high dephlegmation of the spirit by this method, it may be observed, that if a drop or two of water be added to alcohol in which salt of tartar has long remained dry, the alkali immediately becomes moist, and appears to run unctuous from the sides of the vessel.

If the alcohol be *distilled* off the alkaline salt with a gentle heat, the first part which comes over will be about the specific gravity of 0.813 to 0.815, at the temperature of 60°, and this is as high a degree of purity as it has been brought to in the accurate experiments made in this country, by Dr. Blagden and others, for the purpose of ascertaining its specific gravity. (See GRAVITY *specific*.)

M. Lowitz, however, asserts, that he has brought alcohol to the specific gravity of 0.791, chiefly by adding, before distillation, a very large quantity of alkali so as almost entirely to absorb the spirit.

After distillation, the wet alkaline salt which is left may be dried, and again used for the same purpose; but Boerhaave asserts, that after repeating the use of the same alkali for a number of times, it becomes changed in its nature, and unfit for the purpose. This would imply a decomposition of the alcohol, which deserves to be further examined.

Various tests have been devised for ascertaining the purity of alcohol, and the proportion of water which it contains. A spirit, which is very free from water will, when set fire to, burn away without leaving any residue; if it is of moderate strength it will burn for a certain time, and then become extinguished, and leave a portion of water more or less considerable, according to the degree of dephlegmation; if, on the contrary, it is very weak and watery, it will not kindle at all. This test, however, is by no means accurate, since the heat of the burning spirit will drive off part of the water which should be left in the residuum. Another test is, to drop a small quantity of spirit on a small heap of gunpowder and kindle it. The spirit burns quietly on the surface of the powder till it is all consumed, and the last portion fires the powder if the spirit was pure, but if watery, the powder becomes too damp and will not explode. This test, also, is very inaccurate; for if the powder be drenched with even a strong spirit, it remains too damp to be fired; and if it be only barely moistened, any spirit that will burn will inflame it. A better test is, as we have mentioned, to shake the spirit in a phial with some dry carbonated alkali; but the most accurate of all is to ascertain its specific gravity, and compare it with the density of known quantities of alcohol and water, previously mixed for the purpose of giving a standard of comparison. The very extensive and accurate labours on this subject, conducted by Beaumé, Blagden, Gouvenain, and other eminent scientific men, belong with more propriety to the subject of *specific* GRAVITY.

It remains for us to mention the chemical nature of alcohol, and the appearances which attend its decomposition. The remarkable circumstance of a vegetable product burning away, without the smallest trace of smoke or fuliginous vapour of any kind, had long engaged the attention of chemists. Junker and Boerhaave threw much light on the subject by remarking, that the product of the combustion of alcohol was always a quantity of pure water; and this fact was more fully illustrated by the experiments of the illustrious Lavoisier. The ready evaporation of alcohol, and the ease with which its vapour will fill a large vessel, renders it a dangerous experiment to submit a considerable quantity at once to combustion, in oxygen gas confined in any vessel, but this difficulty was surmounted in an ingenious manner. His first experiment was simply to ascertain the quantity of water yielded by the combustion of a given weight of alcohol. This was performed in the following apparatus, contrived by M. Meusmier. See Plates of CHEMISTRY, fig. 10.

E F is a worm, contained in the cooler A B C D. To the upper part of the worm E, the chimney G H is fixed, which is composed of two tubes, one within the other, the inner of which is a continuation of the worm, and the outer one is a case of tin-plate, which surrounds it at about an inch distance, and the interval is filled with sand. At the inferior extremity K of the inner tube, a glass tube is fixed, to which is adopted the argand lamp L M, for burning alcohol.

Things being thus disposed, and the lamp being filled with a determinate quantity of alcohol, it is set on fire; the water which is formed during combustion, rises in the chimney K E, and being condensed in the worm, runs out at its extremity F, into the bottle P. The use of the outer tube G H, and of the sand between it and the inner tube, is to prevent the latter which proceeds from the worm, from being cooled during combustion, which would occasion the water, formed by the burning, to fall back on the lamp instead of passing on into the worm.

This apparatus though not perfect, has the advantage of enabling the chemist to operate with larger quantities than can be admitted in the more accurate experiments on combustion, and by it, the above-mentioned chemists were able to establish the important fact, that the quantity of water collected by the combustion of alcohol *very sensibly exceeds the quantity of the alcohol which is consumed.* The product of water must vary according to the strength of the alcohol, and the care of conducting the experiment; but it is so considerable, that from sixteen ounces of ardent spirit, Lavoisier obtained eighteen ounces and a half of pure water. There is besides, however, a large quantity of carbonic acid produced in this experiment which escapes, and cannot be estimated by this apparatus. Some of this gas unites with the water which is collected, and causes it to precipitate lime-water.

Having thus ascertained in a general way the products

of the combuſtion of alcohol, Lavoiſier proceeded to repeat the experiment, in veſſels which might determine the reſult with accuracy. He employed, for this purpoſe, a large bell glaſs, holding from 700 to 800 cubic inches, and inverted over a mercurial trough. A ſmall lamp, filled with a known weight of alcohol, was introduced under the glaſs ſwimming on the ſurface of the mercury, and the wick was armed with a very minute portion of phoſphorus. The atmoſpherical air within the glaſs was ſucked out by a ſyphon, till the mercury roſe to a certain height which was noted; and the phoſphorus on the wick being then kindled by a hot iron, the ſpirit ſoon took fire. As the air within the glaſs would be ſoon conſumed, and the inflammation of the ſpirit ſtopped, a conſtant ſupply of oxygen gas was ſent into the glaſs through a ſyphon tube, connected with a reſervoir of this gas, and which paſſed under the mercury into the glaſs where the combuſtion was going on. Great precaution was required not to let in more oxygen than was barely neceſſary to keep up the combuſtion; otherwiſe the heat, volatilizing part of the ſpirit, would have filled the glaſs with vapour of alcohol, and this mixing with the oxygen, would have ſuddenly exploded by the combuſtion. In this, as in other reſpects, the combuſtion of alcohol ſtrikingly reſembles that of pure hydrogen gas. The experiment was at laſt ſtopped by the quantity of carbonic acid generated; and on examining the reſults, (proper corrections being made for preſſure and temperature) it was found, that 93.5 grains of alcohol and 110.32 grains of oxygen had been conſumed. The products of theſe were 93.8 grains of carbonic acid and 106.2 grains of water, which laſt therefore exceeded by 12.7 grains the quantity of alcohol employed. From theſe data, and from previous experiments (wherein Lavoiſier eſtimated, that 100 grains of oxygen take up 38.88 grains of carbon, for the production of carbonic acid gas; and that the ſame quantity of oxygen takes up 17.64 grains of hydrogen for the production of water), he concluded the compoſition of alcohol to be the following,

Carbon - - - - - -	28.53
Hydrogen - - - - - -	7.87
Water already exiſting in the alcohol	63.6
	100

We may obſerve, however, that the reſult of this experiment can only be conſidered as an approximation towards the truth, ſince the eſtimation of the component parts of alcohol here given, does not agree with that which is deduced by the ſame chemiſt, from the reſult of vinous fermentation. Neither is there any light thrown on the mode of union between the component parts, and their degree of oxygenation as they exiſt in the ſpirit before combuſtion.

Alcohol has likewiſe been more directly decompoſed without the acceſſion of oxygen gas. Dr. Prieſtley procured inflammable air by paſſing the electric ſpark through ſpirit of wine. But the moſt ſtriking experiments on this ſubject, performed by this excellent philoſopher, were the decompoſition of ſpirit by paſſing it through red-hot tubes, both of earth and metal. He firſt tranſmitted two ounce meaſures of alcohol, reduced to vapour by boiling, through an ignited porcelain tube, and procured 1900 ounce meaſures of air, "which was all inflammable *without* "*any mixture of fixed air in it*, and which burned with "a blue lambent flame." (We here quote the very words of the author, which the writer of the article Alcool, in the *Encyclopedie Methodique*, has made to correſpond with the experiments of Lavoiſier, by adopting the following ſingular tranſlation—*M. Prieſtley, en faiſant paſſer de l'alcool dans un tube d'argile rougi au feu, en a retiré du gas hydrogene mélé de gaz acide carbonique.*) Dr. Prieſtley's next experiments are ſtill more curious, as they determine the exiſtence of carbonaceous matter in ſpirit of wine. Having found intereſting reſults from the tranſmiſſion of the vapour of water through a heated copper tube, he repeated the experiments, only ſubſtituting the vapour of ſpirit of wine for that of water. "In this caſe," he obſerves, "the vapour of the ſpirit had no ſooner entered the hot "copper tube, than I was perfectly aſtoniſhed at the rapid "production of air. It reſembled the blowing of bel-"lows. But I had not uſed four ounces of the ſpirit of "wine before I very unexpectedly found that the tube "was perforated in ſeveral places, and preſently afterwards "it was ſo far deſtroyed, that in attempting to remove "it from the fire, it actually fell in pieces. The inſide "was full of *a black ſooty matter, reſembling lamp-black.*" He then varied the experiment by uſing earthen tubes, placing within them copper filings, and tranſmitting the vapour of alcohol. The copper was, as before, converted into a black friable ſubſtance, obviouſly produced by the addition of carbonaceous matter furniſhed by one part of the ſpirit, whilſt the other part appeared in the form of a copious ſtream of inflammable air. It is however by no means the whole of the charcoal of the alcohol which is detained by the copper, for much of it eſcapes mixed with the inflammable air in the form of fine ſoot, giving the gas the appearance of a denſe black cloud; and when the tube is ſtrongly heated, this volatilized charcoal will give an uniform black coating to any balloon or large veſſel in which the gas is received. Dr. Prieſtley found ſome other metals to undergo a ſimilar change by the vapour of alcohol, but none in ſo ſtriking a manner as copper. On heating ſome of this *charcoal of copper*, as he calls it, in oxygen gas, he found it to burn very readily to a certain point, after which the remainder could not be again kindled. The gas produced by the combuſtion was pure fixed air or carbonic acid.

The excellent Dutch chemiſts, of the Teylerian inſtitution, Van Marum and colleagues, repeated Dr. Prieſtley's experiments with great accuracy, and found the ſame reſults in every eſſential particular. They employed, as well as Dr. Prieſtley, Wedgwood's porcelain tubes, which they incloſed in iron tubes to prevent the ſudden action of the fire which is apt to crack them. One extremity of the earthen tube received a ſmall retort in which was put the alcohol, and the other entered a metallic ſerpentine tube, immerſed in a refrigeratory, and provided at the further end with a bottle to receive the gaſeous products. In the firſt experiment which was performed, an ounce and a half of alcohol in vapour had been tranſmitted through the heated copper, and had produced about ſix cubic feet of inflammable air.

In the ſecond experiment the heat was greater, and the production of the gas more rapid. In all, the copper was reduced to a black and very friable ſubſtance, which fell to pieces between the fingers. The proportion of charcoal added to the copper by the experiments, varied at different times apparently owing to the greater or leſs rapidity with which the proceſs was conducted. Dr. Prieſtley had united 446 grains of charcoal to 28 of copper, in one inſtance; and 508 to 19, in another: but the Dutch chemiſts found a much leſs proportion of charcoal, being only an addition of 292 grains to 748 of copper in one caſe, and in another, 180 of charcoal to 612 of the metal. The great difference in the reſults is, however, of little conſequence in attempt-

ing to ascertain by these experiments the exact proportion of the component parts of alcohol, since a large part of the carbonaceous ingredient escapes the copper, and passes over into the vessels which receive the inflammable air, where it either appears in the form of a fine black soot, or remains permanently united with the hydrogen gas. M. Van Marum likewise collected in the bottle connected with the serpentine a quantity of nearly pure water, about equal to half the weight of the alcohol evaporated by boiling, and of the specific gravity of .996. He does not inform us of the strength of the spirit which he used. He confirmed the other part of Dr. Priestley's experiment by burning the *charcoal of copper* in oxygen gas, and procuring pure carbonic acid, whilst the remaining copper still retained a small portion of carbon which could not be consumed. It is worthy of remark, that the inflammable air produced in the experiments of both these eminent chemists was found to be not much more than twice as light as common air, and it probably bears a considerable resemblance to that species of gas, termed, with great propriety by Mr. Cruikshank, *Gaseous Oxyd* of CARBON.

The vapour of alcohol transmitted through earthen tubes forms, in particular circumstances, that singular air which has been named OLEFIANT GAS.

The uses to which alcohol is applied are numerous and important. In the arts, it is employed largely as a solvent for those resinous gums which form the basis of numerous varnishes and similar applications.

It possesses in the highest degree the cordial, stimulating, and intoxicating qualities of all distilled spirits, and although the less powerful and more grateful of the spirituous liquors, such as rum, brandy, &c. are more peculiarly devoted to the use of the table, the purer ardent spirit, again sufficiently diluted with water, is employed as the basis of many of the artificial cordial spirits and liquors, to which a flavour and additional taste are given by particular admixtures. Similar to this is the use of alcohol in medicine, where it serves as a solvent for the more active parts of vegetables, under the form of tinctures, and it is also employed as an external application, often with considerable success.

The highly antiseptic power of alcohol renders it particularly valuable in preserving particular parts of the body as anatomical preparations.

The gentle, steady, and uniform heat which it gives during combustion, and the absence of smoke or fuliginous vapour of any kind, make it often a most eligible material for burning in lamps.

As a fluid for thermometers, it has the advantage over mercury in not freezing in any known degree of cold, but from its ready volatility in a moderate heat it cannot be depended on with any accuracy, above 90 or 100 degrees.

The expansibility of alcohol is much greater than water; the former being, in a range of temperature from 30 to 100, $\frac{1}{25}$th of its bulk, and the latter only $\frac{1}{145}$th.

The use of alcohol in chemical analysis has been already mentioned. As a solvent for some of the earthy and metallic salts, and a precipitant of others, it is peculiarly fitted to assist in the analysis of mineral waters, and saline substances in general; and in the chemical examination of vegetable and animal matter, it furnishes a solvent of very extensive power, possessed of the valuable advantage to the chemist of producing but little decomposition in the substances which it holds in solution, and therefore enabling him to present them almost exactly with their native properties and distinctive characters.

Boerhaave's Chemistry, vol. ii.—Encyclopedie Methodique Art. Alcool.—Priestley on Air, 2d edition.—Annales De Chimie, tom. xxx.

ALCOHOL is sometimes also used for a very fine, impalpable powder, which women in the East make use of as a kind of *fucus*. Kohol is a general term applied to a substance applied to the eye-ball, on the inside of the eye-lids, in the form of a powder finely levigated. That which is employed for ornament is called simply al kohol, or isphahany; when other ingredients, as flowers of olibanum, amber, and the like, are added, on account of some particular disorders, the kohol is distinguished by some appropriate epithet. Dr. Shaw, in his Travels, speaking of the women in Barbary, says, that none of these ladies think themselves completely dressed, until they have tinged their hair and edges of their eye-lids with *al-ka-hol*, the powder of lead-ore. Lady Montague (Letters, vol. ii. p. 32.) takes notice of this custom among the Eastern women; and in her sprightly manner, she supposes our English ladies would be overjoyed to know this secret. This ore used at Aleppo, called Stibium by the ancients, but very different from antimony, is brought from Persia, and is prepared by roasting it in a quince, an apple, or a truffle, then adding a few drops of oil of almonds, it is ground to a subtile powder on a marble. Of late years the lead ore, brought from England, under the name of Arcifoglio, has been used instead of the isphahany. The quantity of kohol consumed in the East is incredibly great. It has been said by one of their poets, in allusion to the probe used for applying the powder, and the mountains where the mineral is found, "that the mountains have been worn away by a bodkin." This probe or bodkin, called meel, is made of ivory, silver, or wood; it is dipped in water, and when a little of the powder has been sprinkled on it, it is applied horizontally to the eye, and the eye-lids being shut upon it, the probe is drawn between them, leaving the inside tinged, and a black rim all round the edge. The Roman Satyrist alludes to this custom, as well as that of blackening the eyebrows:

> "Illa supercilium madida fuligine tactum
> Obliqua producit acu, pingitque trementes
> Attollens oculos."
>
> JUVENAL, Sat. ii. v. 67, and Casaubon's note.

The kohol is also used by the men for strengthening the sight, and preventing various disorders of the eye, for which purpose different ingredients are occasionally added. It is also applied to the eyes of children, as soon as they are born, and is renewed at the interval of a few days through the several periods of their adolescence. The use of the kohol is of very ancient date. Passages relative to it, in sacred history, may be seen in Shaw, (Travels, p. 229.), Harmer, (Observations, vol. ii. p. 405.), and Lowth's Notes on Isaiah, chap. iii. v. 16. Harmer conceives that the *redness of the eyes*, as it is in our version, which the dying patriarch mentions in blessing Judah, (Gen. xlix. 12.), is to be explained by this usage. Dr. Russell observes, on a passage in Xenophon referred to by Shaw, that blackening the eyes, though a custom among the Medes, was not at that time in use among the Persians; for Cyrus, among other things, seems to have been surprised at the painted eyes of his grandfather Astyages. Cyropæd. lib. i. p. 8. See Russell's Aleppo, vol. i. p. 111. p. 367. Ed. 1794. From this impalpable powder the name was transferred to other subtile powders, and afterwards to spirits of wine exalted to its highest purity and perfection. See PORPHYRISATION.

ALCOHOL, in the Arabian *Astrology*, is when a heavy

ſlow-paced planet receives another lighter one within its orb, ſo as to come in conjunction therewith.

Alcohol *Martis*, filings of ſteel reduced to an impalpable powder, by turning it into ruſt with urine, then levigating it, and mixing it with a large quantity of water; that is, about a gallon to two pounds and a half of filings. After it has ſtood a quarter of an hour, the upper part of the water is to be poured off, and evaporated to a dryneſs. The powder at the bottom is to be put into a paper, in the form of a ſugar-loaf, and waſhed, by gradually pouring in hot water, till it is freed from the urinous ſalts. With regard to the remaining groſs powder, the ſame proceſs is to be repeated.

Muſgrave has a great opinion of this preparation, as a remedy to bring back the gout from the nobler parts to the joints. He preſcribes it thus: take of *alcohol martis* from five to ten grains, *theriaci Andromachi* from half a ſcruple to one dram, mix theſe with as much ſyrup of clove-july-flowers, as is ſufficient to make a bolus.

ALCOHOLIZATION, in *Chemiſtry*, the rectification of a vinous ſpirit.

This is otherwiſe called *alcolization*.

Alcoholization, according to Starkey, denotes the circuition of a volatile ſpirit on a fixed alkali, till ſuch time as out of the two ariſes one neutral body different from both the former. *Alcoholization* is one way of volatilizing alkalis.

Alcoholization is alſo uſed for pulverization.

Ale

Ale, a popular fermented drink, made from malt and hops; and chiefly distinguished from beer, another potable liquor made from the same ingredients, by the quantity of hops used therein; which is greater in beer, and therefore renders the liquor more bitter, and fitter for keeping. For the method of brewing ale, see Brewing. The brewers also distinguish pale, or fine ale, brown ale, &c. Their several properties, effects, &c. see under Malt-*Liquor*.

The art of making an infusion of corn, and particularly of barley, similar to our ale, seems to have been known and practised in very ancient times among those people who lived in climates that did not afford grapes. It seems to have passed from Egypt into those western nations, which were settled by the colonies that migrated from the east. The zythum and curmi, mentioned by Tacitus, as the beverage of the ancient Germans, are supposed by Matthiolus to correspond to our ale and beer. Diodorus Siculus says (lib. iv. c. 26. tom. i. p. 350.) that the Gauls, who lived in a country that produced neither grapes nor olives, made a strong liquor of barley, which they called Zythus. The natives of Spain, the inhabitants of France, and the aborigines of Britain, used this liquor, under the different appellations of cælia and ceria in the first country, of cerevisia in the second, and of curmi in the last; all which names literally denote the *strong water*.

After the introduction of agriculture into this island, ale or beer was substituted for mead, and became the most general drink of all the British nations which practised that art, as it had been of all the Celtic people on the continent. "All the several nations, (says Pliny, H. N. xiv. 29. tom. i. p. 729.) who inhabit the west of Europe, have a liquor with which they intoxicate themselves, made with corn and water, *fruge madidâ*. The manner of making this liquor is somewhat different in Gaul, Spain, and other countries, and it is called by many various names; but its nature and properties are every where the same. The people of Spain, in particular, brew this liquor so well, that it will keep good for a long time. So exquisite is the ingenuity of mankind in gratifying their vicious appetites, that they have thus invented a method to make water itself intoxicate." The manner in which the ancient Britons, and other Celtic nations, made their ale is thus described by Isidorus, (Orig. lib. xx. c. 2.) and Orosius, (lib. iv. p. 259.), cited by Henry (Hist. of England, vol. ii. p. 364, 8vo): "the grain is steeped in water, and made to germinate, by which its spirits are excited and set at liberty; it is then dried and ground; after which it is infused in a certain quantity of water; which, being fermented, becomes a pleasant, warming, strengthening, and intoxicating liquor." This ale was most commonly made of barley, but sometimes of wheat, oats, and millet. Geopon. lib. vii. c. 34. p. 203. This liquor is of such antiquity in England, that we find mention of it in the laws of Ina, king of Wessex. Ale was the favourite liquor of the Anglo-Saxons and Danes, as it had been of their ancestors, the Germans. Tacitus, de Mor. Germ. c. 23. Before their conversion to Christianity, they believed that drinking large and frequent draughts of ale was one of the chief felicities which those heroes enjoyed who were admitted into the hall of Odin. Amongst the liquors provided for a royal banquet, in the reign of Edward the Confessor, ale is particularly specified. In Scotland and Wales they had two kinds of ale, called common ale and spiced ale; and their value was thus ascertained by law: "if a farmer hath no mead, he shall pay two casks of spiced ale, or four casks of common ale, for one cask of mead." By this law, a cask of spiced ale, nine palms long, and 18 palms in diameter, was valued at a sum of money equal in effect to 7*l.* 10*s.* of our present money; and a cask of common ale, of the same dimensions, at a sum equal to 3*l.* 15*s.* Hence it appears, that common ale was at this period an article of luxury among the Welsh, and that it could only be obtained by the great and opulent. Wine at this time seems to have been unknown even to the kings of Wales, as it is not mentioned in their laws; though Giraldus Cambrensis, who flourished a century after the conquest, informs us, that there was a vineyard in his time at Maenarper, near Pembroke, in South-Wales. Henry's Hist. vol. iv. p. 393. By a statute of 35 Henry III. in 1272, mentioned by Hume (Hist. Eng. vol. ii. p. 224.), a brewer was allowed to sell two gallons of ale for a penny in cities, and three or four gallons for the same price in the country. But the first assize of ale was fixed by the famous Stat. 51 Henry II.

The following method for preserving ale from turning sour in long voyages, was first published by Dr. Stubbs (Phil. Trans. N° [illegible]7.), and experience has evinced its utility. To every rundlet of five gallons, after being placed in a cask on ship board not to be stirred any more, put in two new laid eggs whole, and let them lie in it. In a fortnight, or a little more, the egg-shells will be entirely dissolved, and the eggs become like wind-eggs enclosed only in a thin skin; after this the white is preyed on, but the yolks are not touched or corrupted; and by these means the ale has been so well preserved, that it was found better in Jamaica than at Deal.

The duties on ale and beer make a considerable branch of the revenue in England. They were first imposed in 1643, when the excise was first established, again by Car. II. and have been continued by several subsequent acts of parliament. By 43 Geo. III. c. 69, for every barrel of beer or ale, above 16 shillings a barrel, (exclusive of the duty hereby imposed, and not being two-penny ale, nor table-beer, (the brewer shall pay ten shillings; and for every barrel of table beer, or beer or ale of 16*s.* the barrel, or under (exclusive of the duty), two shillings; and for every barrel of two-penny ale, (described in the seventh article of the Union with Scotland) four shillings and two-pence. The allowance for waste shall be three gallons out of 36 gallons, which shall be reckoned a barrel of beer or ale made by common brewers.

The saccharine matter extracted from the farinaceous seeds, of which ales are made, and subjected to a fermentation analagous to that of wine, imparts to our ales a quantity of alcohol; and they have, therefore, in general, the cordial, exhilarating, intoxicating, and sedative qualities of wine. But their effect, in these respects, depends partly upon the quantity and condition of the saccharine matter that is employed, and partly upon the management of the fermentation to which they are subjected. Barley is chiefly employed for the purpose of making ales, though it might be prepared from any of the cerealia; and this selection is very properly made, because its germination is most easily

conducted, and under its germination it gives out its ſugar moſt readily, and in greateſt quantity. Ales, made in the ordinary manner, will be ſtronger or weaker according to the quantity of the ſaccharine matter that is uſed; and this will be greater or leſs according to the quantity of well-ripened farina in the barley that is employed, according to the mode in which it is malted, according to the proper and complete extraction of the ſaccharine matter by water, and according to the diſſipation in a greater or leſs degree, of a quantity of the ſuperfluous water. The other qualities of ales, beſides their ſtrength or weakneſs, will depend upon the conduct of the fermentation. As the infuſion of malt or wort is not ſo well diſpoſed to fermentation as the juices of fruits, it will require the addition of a ferment; and afterwards the conduct of the fermentation will be very much the ſame with that of wines; at firſt very active, and then ſlowly protracted for a long time: but, however ale is managed, its fermentation is not ſo capable of being rendered ſo complete and perfect as that of wine. In moſt ales there is probably a large portion of unaſſimilated farinaceous matter, which of courſe renders ales more nouriſhing than wines, and they are, *cæteris paribus*, more liable to aceſcency in the ſtomach than wines. It has been commonly ſuppoſed, that the viſcidity of worts is never entirely corrected by the fermentation; and therefore that ales are more apt than wines to fill the veſſels of the human body with viſcid fluids; but Dr. Cullen thinks that this circumſtance deſerves little attention, as it is probable that the power of the gaſtric fluid, and of the fermentation which happens in the ſtomach and inteſtines, reduces the whole nearly to an equality in reſpect of fluidity. Cullen's Mat. Med. vol. i. p. 418, &c.

Alkali

ALKALI is the generic term for an order of ſalts of the higheſt importance, and the moſt familiar uſe in chemiſtry.

Alkali is a word of Arabian origin, and it was employed by the Arabian chemiſts and phyſicians, to expreſs the ſalt which was procured from the aſhes left after the combuſtion of ſeveral vegetables, particularly the ſalt *kali* of the deſart, and ſeveral plants growing on the ſea ſhore. The ſame ſalt is alſo found native in immenſe quantities, mixed with ſea ſalt, in the waters and on the ſhores of ſeveral lakes of Lower Egypt, and has been known from time immemorial. by the name of *natron*, or the *nitre* of the ancients. The Greeks and Romans were equally familiar with the alkaline ſalt contained in vegetable aſhes, which was termed lixiviary aſhes (*lixivius cinis*, Plin.), whence the name of *alkaline ley*, *lixivium*, or *lixiviary ſalt*, which is ſtill retained. The uſe of the word alkali was at firſt confined to the ſalt which was yielded by the *fixed* or incombuſtible aſhes of vegetables; but the *volatile* ſalt, which riſes in diſtillation of vegetable, and eſpecially of animal matter, having been found to poſſeſs ſimilar chemical properties with the fixed lixiviary ſalt, in the moſt eſſential

ſential particulars, the reſpective appellations of *fixed* and *volatile alkali* have long been adopted by chemiſts. For the account of the proceſs of procuring theſe ſalts as an article of commerce, for their natural hiſtory, and other particulars, we ſhall refer the reader to the words Potash, Soda, and Ammonia.

The properties common to all alkalies are the following: they have a highly acrid taſte, which acts with ſo much energy upon the tongue as to produce the ſenſation of burning, and unleſs they are much diluted, they very ſoon corrode the thin ſkin which covers it, and produce a ſmall eſchar or dead part, which, for a time, leaves a ſlight ſore on that ſenſible organ. They have an unctuous feel to the finger, not from any oily nature in the alkalies, but becauſe they directly diſſolve the ſurface of the ſkin, and produce a kind of ſoap. They effect a remarkable change on ſeveral vegetable colours. The red of roſes, and the blue of violets, are turned by them to a dull green; the red of archill or litmus, to a blue; the yellow of turmeric, the light brown of jalap root, liquorice root, and of many other roots and woods, are all rendered much deeper in colour, approaching to a brick-red. They unite with ſulphur, forming compounds which have the property of abſorbing the oxygen from atmoſpheric air, and, when moiſtened, of giving out a peculiar fetid gas. Theſe compounds have been denominated *alkaline hepars*, or *livers*, and in the modern nomenclature, *ſulphurets*. They have a very powerful action on almoſt all vegetable and animal matters, producing ſpeedy diſorganization, and diſſolving them into a thick pulp. With oils they form the well-known compound, *ſoap*. They are largely ſoluble in water, giving out heat on union with this liquid. They unite with every acid, and produce *neutral ſalts* of various degrees of ſolubility; in which, when the contents are mutually ſaturated, the diſtinguiſhing properties of both acid and alkali are neutralized, and no longer to be perceived. Owing to the very ſtrong affinity which they bear for acids, they decompoſe the acid ſolutions of all metals and moſt earths. Theſe are the moſt characteriſtic properties common to *all* alkalies; but there are others which are confined to one or other of the two ſpecies. Theſe we ſhall enumerate, referring the reader for more particular information, to the individual articles.

The Volatile Alkali *(Ammonia)* is diſtinguiſhed, (as its name implies) by its volatility. The pureſt form in which it is known to us is that of a gas, which is permanent at any degree of cold that has ever been applied to it, and unites readily with water in large quantity, from which, however, it may be again expelled by a heat much below boiling. It has never been procured in a ſolid form, unleſs combined with ſome other ſubſtance; nor as a liquid, except by its union with water. It differs remarkably from the fixed alkalies in having a very pungent ſmell, which highly ſtimulates the noſtrils, and excites coughing and tears. Owing to the eaſe with which it aſſumes a gaſeous form, it is incapable of uniting with many ſubſtances which the fixed alkalies will diſſolve, when aſſiſted by fuſion in a ſtrong heat. The volatile alkali is weaker in all its affinities than the fixed. It is alſo the only one which is decidedly proved to be a compound ſubſtance; the nature of its conſtituent parts (which are hydrogen and azote) having been aſcertained by numerous experiments both of ſyntheſis and analyſis. See Ammonia.

The Fixed Alkalies, *(Alkali fuerbeſtandiges, Laugenſalz*, Germ-*Alcali* fiſſo Ital.) are the proper *lixiviary* alkalies, or thoſe that are procured by lixiviation of the aſhes of burnt vegetables. They may be obtained in a very pure ſolid form, either cryſtallized, or as a ſimple concrete. Beſides the properties which have been mentioned as common to all alkalies, theſe poſſeſs conſiderable fixity in fire, and at a red heat they run into thin fuſion. A higher heat, however, volatilizes them, and they fly off in ſenſible vapour. The fixed alkalies, when in fuſion, will readily diſſolve ſiliceous earth into the perfectly homogeneous tranſparent compound, glass. They alſo will diſſolve by heat all the metallic oxyds, and thereby receive various tints. They aſſiſt in the fuſion of all earthy and metallic admixtures, and their degree of fixity in the fire enables them to combine more intimately than the volatile alkali, with ſulphur, phoſphorus and charcoal. When pure and ſolid, they are remarkably deliqueſcent, abſorbing water from every ſurrounding medium; and hence they have been uſed by chemiſts to render the air of any veſſel in which they are confined, perfectly dry. The fixed alkalies are two in number, potash and soda, the former being procured from the aſhes of all vegetables except marine plants, and a few that grow near the ſea ſhore, which yield the latter alkali. The former is alſo termed the *vegetable* alkali, and the latter, (owing to its being ſometimes found native in the earth), is called the *mineral* alkali. The general properties of theſe two alkalies were long known, and they were long employed in various arts, before the circumſtances by which they are diſtinguiſhed were well aſcertained, and their ſeparate exiſtence eſtabliſhed. The cloſe reſemblance which they bear to each other when pure, and the ſimilarity in all their moſt remarkable chemical properties, prevented a proper diſtinction between them; and it was chiefly by the reſearches of Pott, Duhamel and Margraaff, that the nature of the two alkalies was fully explained. The two neutral ſalts with which the older chemiſts were the moſt familiar, nitre and ſea-ſalt, have for their baſes, the former the vegetable, and the latter the mineral alkali; and it was principally by enquiries into the properties and decompoſition of theſe neutral ſalts that the diſtinct nature of their alkaline baſes was decided.

Potaſh and ſoda differ from each other in the ſtrength of their affinity with acids, which is greater in the former; in ſome ſlight variation in their action on oils and animal fats; but chiefly in the neutral ſalts which they form with the acids, which in all caſes differ in form of cryſtallization, in ſolubility, often in taſte, and in ſeveral other particulars.

The intimate nature of the fixed alkalies is ſtill unknown to us. From the very ſtrong analogy with the volatile alkali, the component parts of which are fully eſtabliſhed, it muſt be conſidered as highly probable that the fixed alkalies are compounds, though their decompoſition has not yet been effected by any experiments which can be allowed to be unexceptionable. Fixed alkalies have been ſuppoſed to be *generated* by the proceſs of combuſtion of vegetables; ſince no plants, even thoſe whoſe aſhes yield the moſt of this ſalt, contain before combuſtion any ſenſible quantity of uncombined alkali. The accurate analyſes of ſeveral of the modern chemiſts have however detected, in the native juices of plants, ſeveral neutral ſalts, whoſe alkaline baſes are united to an acid which is eaſily deſtructible by fire. But for this, and other ſpeculations on the nature of the fixed alkalies, we ſhall refer the reader to the article Potash.

Alkali *(Cauſtic or Pure)*. The alkaline ſalt procured from vegetable aſhes, beſides being mixed with other ſalts, and with earth, is always ſaturated more or leſs completely with fixed air, or *carbonic acid*; ſo that the fixed alkali which was the ſubject of the experiments of all the chemiſts, till within a few years, was a ſalt compounded of carbonic acid and the alkaline baſis. The beautiful experiments of Dr. Black fully illuſtrated this point, and ſhewed, that the reaſon of the greatly increaſed cauſticity of alkalies, when mixed with quick-lime, was the loſs of the carbonic acid, which had paſſed from the alkali to the earth. *Cauſtic* alkalies, there-

fore, are alkalies deprived of carbonic acid by quick-lime or any other method; and this is the only ftate in which, properly fpeaking, alkalies can be confidered as *pure;* though even when they contain much of this volatile acid, the peculiar qualities of the alkaline part predominate fo confiderably as to enable them to exhibit (though in a weaker degree) all the chemical properties by which alkalies are characterized.

Alkali *(Effervefcent or Mild)*, is oppofed to the ftate of caufticity, and expreffes that degree of faturation with carbonic acid, which, as has juft been mentioned, diminifhes, but does not fupprefs, the characteriftic properties of the alkali. Owing to the alkali obtained from vegetable afhes being always left after combuftion in union with carbonic acid, *effervefcence with acids* was confidered by the older chemifts as an effential character of alkalies in general, who thus afcribed to a property inherent in this genus of falts, an appearance which is now known to depend upon the expulfion of the gafeous acid. The terms *cauftic* or *pure*, and *effervefcent* or *mild*, are applied to the volatile as well as to the fixed alkalies.

Alkali *(Extemporaneous)*, is a mild vegetable alkali, prepared by deflagrating nitre with tartar. See Carbonat of Potash.

Alkali *(Fluor)*, is a folution of pure Ammonia in water.

Alkali *(Phlogiftic)*, is prepared by calcining carbonated potafh with bullocks' blood or other animal matter, in which procefs it unites with the Prussic acid, formed during the calcination.

Alkali *(of Tartar)*, or *Salt of Tartar*, is properly a mild vegetable fixed alkali, prepared by the combuftion of tartar, which yields it in great purity. The name is ufed more extenfively for any pure carbonated potafh, and it is the term by which this falt is more generally known in common language and in medicine.

ALKALINE EARTHS. It is by no means eafy to draw the line accurately between alkalies and earths. The original idea of an earth, entertained by the ancient chemifts, was that of a fubftance of confiderable denfity, infoluble in water, without tafte, fmell, or any perceptible action on the organs of fenfe, entirely unfufible, and fixed in the moft intenfe fire; and, in fhort, with properties as oppofite as poffible to thofe of a salt. This opinion principally attached to earth, confidered as one of the four elements of which the material world was fuppofed to be conftituted. The progrefs of chemical inveftigation having, however, difcovered feveral fpecies of earths, which could not by any means be proved to be compounds, in which the fimple or univerfal earth was fo difguifed as to lofe fome of its effential characters, it became neceffary to alter and modify the original definition of an earth, and to allow to it more of a faline nature.

Some of the modern chemifts, therefore, have adopted the term *falifiable*, and others *alkaline* earths, in order to allow of more accuracy in fyftematical arrangement. By *alkaline* earth has been meant an earth which agrees with alkali in the property of folubility in water to a certain extent, and thereby rendering it fapid, of changing to green certain blue and red vegetable colours; of abforbing carbonic acid with eagernefs, and of poffeffing, when pure, thofe *cauftic* or acrid qualities that fo much diftinguifh the alkalies. *Magnefia, lime, barytes* and *ftrontian*, are the earths which may be termed alkaline, but the former is very imperfectly fo, being fcarcely more foluble in water than filex; and though its habitudes with carbonic acid are partly fimiliar to thofe of the alkalies, it does not acquire any tafte, or any degree of caufticity, by the lofs of this gafeous acid. Barytes and ftrontias, on the other hand, approach nearer to an alkaline nature than lime, in being very largely foluble in water, and readily cryftallizable from its folution in a determinate form. They have therefore been actually enumerated as alkalies by Fourcroy, who reckons the following; *potafh, foda, ammonia, barytes*, and *ftrontian*. The two latter even ftand before the three ancient alkalies in their order of affinity with moft acids, but, till the intimate nature of the fixed alkalies be fully cleared up, it will perhaps be proper to reftrict the term *alkali* to the three above-mentioned, and to retain in the clafs of *alkaline earths* magnefia, lime, barytes, and ftrontian, all of which, however they may be alkalies in many refpects, differ from them in being unfufible *per fe* in very intenfe fire, and being entirely incapable of being volatilized by the utmoft heat that has ever been applied to them.

Alkali, in *Botany*. See Salicornia.

ALKALINE, in a general fenfe, fomething that has the properties of an Alkali.

In this fenfe we fay, alkaline falts, alkaline fpirits, alkaline fubftances, &c.

Alkaline falts, confidered in their reference to the *Materia Medica*, are known to poffefs antifeptic powers. Experiments upon them, out of the body, fufficiently indicate and atteft thefe powers; but Dr. Cullen obferves, that it is at the fame time equally well known, that they are conftantly imbued with fuch an acrimony, that they cannot by themfelves be introduced into the body without acting more by their ftimulant than by their antifeptic powers. The volatile alkali may fometimes be an ufeful remedy in putrid fevers; but it cannot, as fome have imagined, be given more freely on account of its antifeptic powers, as it can never be given copioufly enough to have any effect by thefe qualities. The volatile alkaline falts fhew their ftimulant power in every dofe, wherever the energy of the brain is weakened, and confequently the action of the heart is languid, or requires to be accelerated. In fuch cafes this ftimulus is among the fafeft, as it is always tranfitory; and when their acrimony can be covered, fo as to pafs the mouth and fauces without irritation there, they may be given in large dofes from 10 to 20 grains. Thefe are prepared in two different ways; one of which is from fal ammoniac, which gives the ammonia of the London Difpenfatory, or the fal ammoniacus volatilis, and fpiritus falis ammoniaci of the Edinburgh. Thefe are the pureft forms of the volatile alkali, the moft free from any adhering animal fubftances; but whilft the procefs of preparing a volatile alkali from the bones or other folid parts of animals continues, there will come into the fhops a falt and fpirit that can hardly ever be fo pure, from fome empyreumatic animal fubftance adhering to it; and fuch an adherence may probably give fome peculiar quality to the falt and fpirit, and render it more antifpafmodic. It cannot be very confiderable in any dofes of the falt or fpirits given to adults, but it may produce more fenfible effect in the fpafmodic affections of infants. The liquid volatile alkali is commonly employed in its mild ftate; but by a diftillation of the fal ammoniac with quick-lime, the alkali may be obtained in its cauftic ftate. In this ftate it may be readily joined with fpirit of wine, and gives the fpiritus falis ammoniaci of the Edinburgh Difpenfatory, or the fpiritus falis ammoniaci vinofus of that of London. The combination affords an excellent menftruum for diffolving the feveral fetid fubftances employed as antifpafmodics, and renders them more fuddenly diffufible, and perhaps gives them a greater effect in all fpafmodic affections. The cauftic volatile alkali is feldom adminiftered alone; but if its acrimony be covered while it paffes the mouth and fauces, it may be very fafely employed. Its chief ufe is external, and when fmelled at the nofe, it gives a more powerful ftimulus than the mild alkali can do. Its acrimony is fo confiderable, that when applied to the fkin, it

readily irritates, and even inflames it, and may be ſo managed, as to prove an uſeful ſtimulant and rubefacient in many caſes. But this requires its being blended with a mild, expreſſed oil, ſo as to prevent its inflaming too much. See *Volatile* OIL. The fixed alkaline ſalts have been commonly adminiſtered as diuretics. Dr. Cullen has chiefly employed the vegetable fixed alkali, and has ſometimes obtained its effects in a remarkable degree; but he has been often diſappointed, which he aſcribes to the neutralization of the alkali in the ſtomach, and in that ſtate they could have no other effect than other neutrals, which is commonly inconſiderable, either as laxatives or diuretics. Alkalines do, however, occaſionally manifeſt their diuretic power: and upon the ſuppoſition of their neutral ſtate in the ſtomach, their conſiderable operation as diuretics cannot be eaſily accounted for. Of this fact Dr. Cullen offers two explanations. One is, that the quantity of alkali thrown into the ſtomach may be more than the acid can there neutralize, and therefore ſome portion of it may reach the kidnies in its alkaline ſtate, and prove a more powerful ſtimulant than any neutral ſalt would be; and on this ground a large quantity of alkali is always neceſſary to produce diuretic effects. Another explanation of the fact is as follows. As the acid of the ſtomach may be preſumed to be of the nature of the fermented acid of vegetables, ſo an alkali joined with it muſt form a regenerated tartar, a ſal diureticus, or kali acetatum; and if this be leſs purgative, and more diuretic than other neutrals, while it is alſo conveyed to the blood-veſſels in larger quantity, we can underſtand why, from theſe circumſtances, the fixed alkali may often appear diuretic. With reſpect to its operation as a diuretic, another conjecture may be offered. When it is given with bitters, after the manner of Sir John Pringle, it commonly proves diuretic; and Dr. Cullen imagined, that as the bitters are abſorbents of acid, they might abſorb ſo much of that preſent in the ſtomach, as to prevent its being ſo fully applied to the alkali. As alkalines may be often prevented, by purging, from reaching the kidnies, ſo their diuretic effect may be often more certainly ſecured by giving an opiate at the ſame time; and for the utility of this practice, ſee Dr. Mead on the ſubject of Dropſy. Beſides the laxative and diuretic powers of the fixed alkali, another is aſcribed to it, which is that of diſſolving the fluids, or the concretions which may happen to be formed in them, expreſſed by French writers under the denomination of *fondant*. Dr. Cullen does not allow it to poſſeſs this power to any great degree, or to produce the effects in this way that have been aſcribed to it. Cullen's Mat. Med. vol. i. p. 568. Vol. ii. p. 382. 512.

ALKALINE *acrimony*, in *Medicine*, ſignifies a morbid quality in the blood, which is indicated by a deſire of and thirſt after ſour things, loſs of appetite, and averſion to alkaleſcent food, nidorous eructations, putrid ulcers on the lips, tongue, and other parts in the mouth, ſickneſs in the ſtomach, a frequent *diarrhœa*, a ſenſe of heat, laſſitude, and general uneaſineſs, a diſſolution of the texture of the blood, the urine high-coloured and red. It produces a putreſcency in the blood, &c. and is to be remedied by the ſame means as the ſea-ſcurvy and other putrid diſorders.

ALKALIZATION, ALKALIZATIO, in *Chemiſtry*, the act of impregnating a liquor with an *alkaline* ſalt.

This is done either to make it a better diſſolvent, for ſome particular purpoſes; or to load the phlegm, ſo as it may not riſe in diſtillation, whereby the ſpirituous parts may go over more pure.

ALKALIZATION, is a name applied to operations, by which alkaline properties are communicated to bodies; or to thoſe by which alkali is extracted from bodies which contain it, or in which it may be formed; e. g. *ſpirit of wine* is ſaid to be alkalized, when it has been digeſted upon alkali; a part of which it diſſolves, and thence acquires alkaline properties. On the other hand, when a neutral ſalt is decompoſed in order to obtain its *alkaline* baſis, this ſalt is to be alkalized. Vegetable ſubſtances, when reduced to aſhes, may alſo be ſaid to be alkalized, becauſe the aſhes contain fixed alkali.

Alum

ALUM, *ores of*, in *Mineralogy*. Under this head we include all those minerals which either contain alum ready formed, or are capable of yielding this salt by the process of manufacture. They may be conveniently divided into three families. 1. The saline, all the species of which are almost wholly soluble in water; 2. The earthy-saline, in which the soluble particles are diffused through a large proportion of earth; 3. The earthy, which containing no alum but only the materials of it, are insoluble and destitute of that sweetish astringent taste, which is characteristic of the two former.

I. Family—SALINE. Taste aluminous, almost wholly soluble in water.

Species 1. Capillary alum.—*Vitriolum halotrichum*, Werner.—*Haarsaltz*, Germ.—*Termes timso*, Hung.

The colour of capillary alum is either pure or yellowish white, passing into isabella yellow and grey, upon exposure to the air. It occurs in long very tender capillary crystals accumulated on an earthy base, or amorphous or tooth-shaped. Its external lustre is glassy and generally glimmering, advancing sometimes to the little-shining, in the pure white varieties approaching more or less to the mother of pearl lustre; internally it is shining or little-shining with a glassy lustre. The amorphous has a fine, straight or curved fibrous fracture. It flies, when broken, into indeterminate not particularly sharp fragments. It appears sometimes to contain slender columnar distinct concretions: is transparent, soft, and very brittle; though each separate crystal has a slight elasticity: sp. grav. according to Scopoli 1.835: has a sweetish astringent taste.

By the analysis of Scopoli, it is soluble in three times its weight of water, and consists of alum and sulphated iron. It is met with at Cremnitz and Chemnitz in Hungary, also in the quick-silver mines of Ydria, where it has generally been mistaken for white vitriol.

Species 2. Plume alum.—*Alumen nativum s. plumosum*, Werner.—*Naturlicher s. feder alaun*, Germ. *Fjädar alun*, Swecd.—*Fiaeragtig alaun*, Dan. *Alun de plume*, Fr.

The colour of this substance is yellowish or greyish white. Its external lustre is dull, but sometimes glimmering, or even little-shining. It consists of slender irregular hair-shaped fibres, either single or accumulated, and slightly adherent to each other; is seldom stalactitic or amorphous. It is usually opaque, but sometimes also transparent or semitransparent. It excites the same taste on the tongue as the preceding species.

It is found efflorescing on bituminous schistus at Göttwig in Austria, on grey argillite in Carinthia, in clefts and caverns on Stromboli, the Solfatara, the grotto of St. Germano, Miseno, and other places in Italy.

In Klaproth's Essays is an analysis of the native alum of Miseno, from which it appears, that 100 parts yield by simple solution and crystallization 47 of perfect alum, and 29 more by the addition of the necessary quantity of potash, the remainder being sand with a little selenite, and a small trace of oxydated iron.

Species 3. Mountain butter.—*Vitriolum alumen butyraceum*, Werner.—*Bergbutter*, Germ.

Its colour is of a more or less dun isabella yellow, or yellowish brown. It occurs amorphous commonly overlaying the surface of aluminous schistus in lumps or clots. Internally it is shining, with a waxy lustre. At first it is very soft, but by exposure to the air it becomes of a middle consistence, between crumbly and compacted, and is then of a strait shivery fracture. Its fragments are indeterminate, blunt. Its distinct concretions are small and fine granular. It is transparent on the edges, and slightly elastic; feels somewhat unctuous, and leaves on the tongue an acerbly sweetish astringent taste.

It occurs in many places where the aluminous schistus is plentiful, and exposed to the air, as at Muskaw in the Oberlausitz: is also found in Siberia.

It has not yet been analysed, but probably differs from the preceding, in containing a larger proportion of clay and iron ochre.

II. Family. Earthy-saline. Taste aluminous, very little soluble in water. All the ores that belong to the third family are occasionally found to have undergone a natural change, similar to what is produced in them by art at the alum manufactories; in consequence of which they often yield, by lixiviation, a variable proportion of alum, and exhibit the sweetish astringent taste peculiar to this salt. 1. Upon the purely sulphureous ores or alum-stone with its varieties, this alteration seems to take place by the action of subterranean fire: alum is also probably formed in mere earthy compounds of silex and alumine, that contain no sulphur when they overlie heated sulphureous strata, by which they are first cracked and then penetrated with sulphureous acid vapours. Examples of both these occur in Italy at La Tolfa, not far from Civita Vecchia, and the Solfatara in the Neapolitan dominions; from 100 parts of which Bergman obtained by mere lixiviation eight parts of perfect alum. 2. The well known property of pyritous and pyrito-bituminous matters to heat, and afford vitriolic salts by the combined action of air and moisture, may also be traced, though in a slighter degree, in the aluminous ores of this description; hence it is that the upper strata of the softer aluminous schistus, of the alum earth, and the sulphureous peats are occasionally impregnated with alum. The marshy black soil of Arragon, that yields pure alum by lixiviation (Bowles's Spain, p. 388.), appears to be of this kind; also the aluminous turf of Helsinborg in Scania (Bergm. Ess. vol. i. 353.); and a vein of black earth in the Shetland islands, containing alum and sulphated iron. Alum is also extracted from fossil wood in Hesse, (Vogel. p. 322.) Springs in the neighbourhood of these strata sometimes hold a little alum in solution, as those near Halle (Chym. Ann. 1788. p. 224.)

Family III. Earthy—no aluminous taste—not soluble in water.

Species 4. Alum-stone. *Argilla aluminaris Tolfensis*, Wern. *Alumen lapid. calcar. mineralizat.* Wall.—*Alaunstein, alaunkalchstein*, Germ.—*Alunsten*, Swecd. *Alunrig steenleer*, Dan.—*Pierre alumineuse de la Tolfa. Pierre calcaire alumineuse*, Fr.—*Pietra calcinosa aluminosa*, Ital.

Alum-stone is greyish or yellowish white, isabella yellow, or light smoak grey; amorphous. Its internal lustre is dull, seldom glimmering. Its fracture uneven, splintery. Fragments indeterminately sharp-cornered. It has distinct conchoidal concretions, which might be mistaken for a fine schistose texture. Is slightly transparent at the edges. Is half-hard passing into hard. Brittle, insipid, feels meagre; and adheres slightly to the tongue.

Its sp. grav. according to Kirwan, is 2.424. It has an earthy smell, and when projected on a red hot iron it hisses and gives out a black smoak, a slight sulphureous smell, and the residue acquires a reddish colour. According to Monnet's analysis, it consists of sulphur and clay, in nearly equal proportions, together with a little iron and potash. Bergman found it to contain about 43 sulphur and inflammable matter, 35 alumine, and 22 silex.

It is found in masses and veins running through argillaceous rocks at La Tolfa, in the states of the church, and in the ore from which the Roman alum is prepared. A volcanic origin has been generally attributed to it, but apparently without reason, as the veins of La Tolfa have been traced into the Apennines. It was formerly supposed to be mostly calcareous, as is evident from the synonims quoted above. La Metherie (Theorie de la Terre, vol. ii. p. 215.) has hazarded an opinion that it is principally alum supersaturated with alumine, and therefore earthy and insoluble. This is a notion which derives high probability from the recent analysis of this ore, by Vauquelin (An. de Chem. vol. xxii. p. 275.) who obtained from it

Alumine - -	43.92
Sulphuric acid	25.
Potash - -	3.08
Water - -	4.
Silex - - -	24.
	100.00

A similar kind of ore has been discovered in rocks near Poliniere in Brittany.

Species 5. Alum-slate. *Aluminous schistus, alaunschiefer*, Germ.—*Alun skifer*, Swecd.—*Ardoise alumineuse*, Fr.—*Lavagna aluminosa*, Ital.—*Timsó pala*, Hung. *Kwasszowoi schifer*, Russ.

Of this there are two varieties.

Var. 1. Common alum-slate. *Gemeiner alaunschiefer*, Germ.—*Argilla aluminaris schistosa vulgaris*, Werner.

Its colour is bluish black, sometimes greyish black. Amorphous, or in concentric balls imbedded in the strata. Its internal lustre is glimmering, or dull. Fracture strait or curved slaty. It flies when broken into broad shivers, or trapezoidal fragments. Gives a grey streak; feels rather smooth but meagre. Is soft, brittle, and but little elastic.

Var. 2. Shining alum-slate.—*Glanzender alaunschiefer*, Germ.—*Argilla aluminaris schistosa nitida*, Werner.

It is of a bluish black colour, generally passing into the iron black—occurs amorphous, in large strata. The lustre of its parallel fracture is shining or even brightly shining, with a lustre between common and semi-metallic: that of its cross fracture is dull, or at most glimmering. Fracture thick and curved slaty, seldom thin slaty. Its fragments therefore are sometimes thick and sometimes thin shivery. It feels smooth; is half hard; brittle; and but little elastic.

Both varieties are found in Norway, at Whitby in England, in Sweden, in Saxony, and various other provinces in Germany. The alum of Great Britain and the north of Europe is almost entirely made of it, for which use the second variety is said to be the best adapted. It commonly occurs in the neighbourhood of coal, and seems to differ in no respect from the bituminous shale impregnated with pyrites.

Species 6. Alum-earth — *Pyritaceous clay, alaun erde* Germ.—*Argilla aluminaris bituminosa*, Werner. *Alunjard*, Swed.—*Terre alumineuse*, Fr.—*Timsös föld*, Hung.

It has a light or dark blackish brown, brownish black, or blackish grey colour. Occurs in large strata of earthy or irregularly slaty masses. It is generally dull, but when containing scattered particles of mica, becomes occasionally glimmering. Its fracture is between compact earthy and imperfectly slaty. Its fragments are partly flaky and partly irregularly blunt cornered. Its streak has a feeble lustre. It is very soft, and may be rubbed to powder between the fingers; is brittle, and of very little elasticity.

When placed among burning coals, it generally blazes a little; and when moistened and exposed to the air in large quantities, it heats and not unfrequently inflames. From 100 parts of it, after torrefaction, Klaproth obtained 10 alum, 7.25 sulphated iron, 2.25 sulphated lime, and 1 sulphated magnesia.

It is found in alluvial and secondary strata, and is intimately connected with bituminous wood, alum slate, and coal shale. Is used in the manufacture of alum in Germany.

Lenz, Versuch der Mineralien.—Widenman, handbuch der Mineralogie.—Lametherie, Theorie de la terre.—Bergman's Essays—Klaproth's analytical Essays.—Kirwan's Mineralogy.

ALUM, *Manufacture of.*

In order to appreciate rightly the peculiar advantages or disadvantages of the several methods of manufacturing this salt, it will be necessary to enter into a previous enquiry concerning the nature and proportions of its elements, and the different chemical varieties of alum, which have hitherto been confounded under the same name.

§ 1. *Analysis and Composition of Alum.*

The identity of the earthy base of alum with pure clay, was first ascertained by Geoffroy and Hellot, and the successive experiments of Pott, Margraaf, and Macquer, upon the same subject, put an end to the controversy concerning the nature of aluminous earth, which has ever since been universally received as the same with pure clay or alumine, according to the reformed nomenclature. The acid in alum has always been considered as the sulphuric, and the only question among chemists on this head is whether the acid is necessarily in excess. A solution of alum reddens litmus paper, and exhibits other properties of an uncombined acid; but on the other hand it is contended by Morveau, that crystallization and edulcoration would effectually separate any such excess, and therefore that the change of vegetable colours is not an unequivocal proof of superabundant acid. Reserving the consideration of this and similar cases till we come to treat of the article SATURATION, it is sufficient to observe here, as indeed Bergman has clearly shewn, that the acid exists in alum with two very different degrees of affinity. By the action of iron filings on a solution of alum, all the signs of uncombined or loosely adhering acid are destroyed, sulphated iron is produced, and a white earthy precipitate takes place, consisting of the alum deprived of a small portion of its acid, but still retaining the greater part, as may be proved by the further decomposition of it by a caustic alkali; and to this superabundant or slightly combined acid, is entirely owing the taste, the solubility, and most of the other external characters of the salt.

The component parts of alum, according to Bergman, are 38 sulphuric acid, 18 alumine, and 44 water of crystallization. Observing, however, that those solutions, which contained a great excess of sulphuric acid could not be brought to crystallization by the addition of lime, soda or barytes; but only by means of potash or ammonia; finding also sulphat of potash in many species of alum, he appears often induced to believe that the alum of commerce is a triple salt consisting of sulphuric acid, alumine and potash. The subject remained in this state of uncertainty till it came under the notice of the most eminent analyst of modern times, the accurate and indefatigable Vauquelin, to whose admirable Memoir on the combinations of alumine with sulphuric acid, we are indebted for the final illustration of a question of equal importance to the chemist and manufacturer.

In order to ascertain the component parts of alum, and to determine the necessity and peculiar agency of alkalies in its preparation, he dissolved in pure sulphuric acid some alumine equally pure; the solution was evaporated several times to dryness to drive off the excess of acid, and the dry and pulverulent residue being then re-dissolved in water, was brought by evaporation to various states of specific gravity for the purpose of crystallization; but, notwithstanding every precaution, a soft magma, consisting of crystalline flakes, was all that could be procured. The solution, which had thus constantly refused of itself to afford crystallized alum, began to deposit some immediately on the addition of a few drops of potash, and by gradually adding the alkali, drop by drop as the deposition of alum ceased, the whole was converted into pure alum, without the smallest mixture of sulphated potash.

Another portion of the same pure aluminous sulphat was mixed with carbonated soda, but without obtaining any crystals. Nor were lime or barytes more efficacious.

Hence it appears plainly that the use of potash is not merely to engage the excess of acid, otherwise soda, barytes and lime, ought to have produced the same effect. Again, if potash and ammonia unite only to the superabundant acid, the sulphats of potash and ammonia should occasion no change in the pure aluminous sulphat; but, on the contrary, if they form an essential constituent part of alum, then they should produce the same effects when combined with sulphuric acid, as when pure. To ascertain this, a solution of sulphated alumine was mixed with a few drops of sulphat of potash, the immediate effect of which was the production of octahedral crystals of alum. Sulphat of ammonia produced the same result.

It might still, perhaps, be objected that the action of these salts, as they are remarkably greedy of sulphuric acid, determined the crystallization of the alum, by the simple absorp-

tion of superfluous acid. In order to determine this, some uncrystallizable aluminous sulphat was mixed with acidulous sulphat of potash, and afforded as great an abundance of alum as when the neutral sulphat of potash was made use of. Hence, no doubt can remain concerning the influence and particular mode of action exercised by potash and ammonia in the manufacture of alum.

The experiments of Bergman and of several other chemists ascertained, that when a solution of common alum is boiled with a quantity of pure alumine, this last combines with it, and forms a peculiar salt insoluble in water, known by the name of neutral aluminous sulphat, or alum saturated with its own earth. To this fact was added another of equal importance, by Vauquelin, namely, that the earthy salt thus precipitated retains its potash or ammonia, for by digestion in dilute sulphuric acid, it is dissolved, and affords octahedral crystals of alum; it even appears from the memoir of this philosopher quoted above, that the presence of one of the two alkalies is necessary to the formation of this neutralized alum. To an uncrystallizable solution of sulphated alumine perfectly free from alkali, he added some pure alumine, and found that a part of it was dissolved to the complete saturation of the acid, but that no precipitation took place; having then added a few drops of sulphat of potash, a precipitate was deposited shortly after, possessing all the properties of the foregoing saturated alum. Hence is established the necessity of sulphated potash or ammonia, to enable alum, by combining with a larger proportion of its base, to pass to the earthy state.

The alum of commerce always contains sulphat of potash either alone or mixed with sulphated ammonia, and as it is often of consequence to the manufacturer to know the absolute and relative proportions of these salts, the following method of analysis may be had recourse to. First, let a small piece of the alum be reduced to powder, and mingled with a solution of caustic potash in sufficient quantity to decompose it entirely: if then, upon gently heating, it gives out an ammoniacal odour, as is generally the case, this indicates the presence of sulphated ammonia. Having obtained this indication, let two or three hundred grains of the alum be dissolved in distilled water and put into a tubulated retort, and then add quick-lime, equal in weight to the salt: by making this mixture boil for about twenty minutes, the whole of the ammonia will be expelled, and may be condensed by cold water in the receiver, or a Woulfe's apparatus: this ammoniacal liquor, being then carefully saturated with sulphuric acid and crystallized, will shew the quantity of sulphated ammonia. The residue in the retort being mixed with warm water and filtered, a clear liquor will be obtained, containing the sulphat of potash, with some selenite; this latter will be precipitated by boiling and evaporation, and the remaining fluid will then deposit the sulphat of potash in a crystalline form. When the previous assay does not indicate the presence of ammonia, the alum is to be decomposed by caustic ammonia, the precipitate is to be well washed, and the liquors being added together, are to be gently evaporated to dryness; the salt thus obtained is to be heated in a crucible till it ceases to exhale white vapours of ammoniacal sulphat, and the residue is sulphat of potash.

§ 2. *Manufacture of Alum from the saline-earthy ores.*

The only place where this kind of ore is found in sufficient abundance to be worth working, is at the Solfatara, a few miles from Naples. The Solfatara, called by the ancients *Forum Vulcani, Campi Leucogei,* is a small plain, at the top of a hill, covered with a white soil, and exhaling sulphureous vapours which, during the night, emit a pale blue lambent light: the ground, even at the surface, is considerably warm, proceeding, no doubt, from subterranean fire. It has continued in nearly the same state from the age of Pliny to the present time, and is celebrated by this author in his Natural History (lib. xxxv. ch. 50.) for its sulphur, but not for its alum, as the Abbé Mazeas affirms. On the contrary, by his omission of the Campi Leucogei, when mentioning the various places from which alum was then procured, it is plain that the establishment of the alum works of the Solfatara is of more recent origin. The white clayey soil of this plain, being constantly penetrated by sulphureous vapours, and the exhalations during the night being for the most part mixed with the dew, and thus returned upon the surface, cause it to be covered with a light saline efflorescence. This, together with the earth to which it adheres, is daily collected and distributed into leaden cauldrons, so as to fill about two-thirds of their capacity; water is then added, till it stands about three or four inches above the surface of the clay, and this, in a few hours, by the assistance of the natural heat of the ground in which the cauldrons are set almost up to the brim, extracts the alum diffused through the clay, and deposits it in rough crystals on its surface. These crystals being taken out and washed in the mother liquor, are put with fresh water into other boilers, and again dissolved as before, by the natural heat of the ground; the solution is then run through a filter into large wooden coolers, and in a day or two affords a large quantity of pure colourless crystals. Hence it appears that the alum exists ready formed in the earth of the Solfatara, and the whole of the manufacturing part is reduced merely to lixiviation and purification. The proportion of salt must necessarily be very variable, those parts that are exposed to the rain, and that lie above the general level, will contain the least. A specimen that was analyzed by Bergman yielded eight per cent. of alum. The Abbé Mazeas, from six pounds of the earth, procured, by lixiviation, two pounds and a half of crystals, or about 41 per cent. The alum itself has not yet been analyzed; it seems probable, however, that its alkaline part is entirely potash.

§ 3. *Manufacture of Alum from alum stone.*

It is at La Tolfa, not far from Civita Vecchia, in the Roman state, that the manufacture of alum from this species of ore is principally carried on. All the alum known in commerce by the name of Roman alum is thus prepared, as well as the Levant or Smyrna alum.

The ore of La Tolfa forms veins of considerable hardness, which are separated by means of blasting from the rest of the rock; the pieces thus obtained are brought to the calcining oven, which is merely a hole dug in a rising ground, four or five feet in diameter, and from five to six in depth, with a lateral gallery, communicating with the open air, and the bottom of the furnace. The bottom being covered with faggots of brush-wood, the pieces of ore are skilfully laid over them, so as to form a kind of hollow vault, between the interstices of which is an ample passage for the smoke. As soon as the fire is kindled and the flame begins to appear between the stones, a workman is at hand to regulate the combustion, that it may be neither too great nor too feeble; in the course of from three to five hours the smoke begins to decrease, and the fire burns brightly; this is allowed to go on till the smell of burning sulphur begins to be prevalent, which is a sign that the ore is sufficiently roasted. The fire is now raked out, and the stones are left to cool. The sign of this first process being well conducted, is, that

the ore has now acquired the ſweetiſh aſtringent taſte of alum.

The ſecond proceſs begins by piling the calcined ſtones in long beds, on a ſloping floor, the lower ſide of which is terminated by a ditch of water, extending along its whole length; from this ditch the beds are frequently ſprinkled, and the water draining from them returns again into the reſervoir. In about a fortnight the ſtones begin to crack and break down, and are at length, in forty days, more or leſs, overſpread with a reddiſh efflorеſcence, and reduced into a kind of paſte. A leaden boiler is now half filled with water, and when hot, freſh portions of the prepared ore are continually ſtirred in till a ſolution of ſufficient ſtrength is procured; the liquor as yet turbid is drawn off into another boiler, where it is ſubjected to a very gentle evaporation, at the ſame time that it becomes clear by the depoſition of its earth. Having arrived at the point of cryſtalliſation, it is transferred by means of a pipe into a ſquare wooden veſſel, eight feet high by five wide, ſo conſtructed as to be readily taken to pieces; after remaining here for a few days, the mother water is poured out, to be boiled again with freſh alum ore in the firſt cauldron, and the cryſtals, when dried, are ready for ſale.

From this account of the proceſs, by an eye-witneſs (the Abbé Mazeas), it would appear that no potaſh or ammonia is added to the lixivium; it follows, therefore, that one or both theſe alkalies muſt be found in the ore, and this is actually the caſe, according to the analyſis, by Vauquelin, already quoted in the preceding article.

The nature of this ore has been long miſunderſtood, as well as the rationale of its manufacture, and the analyſes of it undertaken by Bergman and Monnet have only ſerved to perpetuate the error. Both theſe chemiſts found a large proportion of ſulphur in it, while Vauquelin finds only ſulphuric acid; this apparent contradiction, however, may eaſily be reconciled, by conſidering that the ore contains carbonaceous matter enough to blacken it, and to give out a light flame when powdered and ſpread on a hot iron; hence, if the analyſis of Bergman and Monnet was begun by diſtillation in a cloſe retort, as it probably was, the decompoſition of the acid and production of ſulphur is readily accounted for. Admitting then the proportions of this ore, as aſcertained by Vauquelin, to be ſufficiently correct, *viz.* alumine 43.92; ſulphuric acid 25.; potaſh 3.08; water 4.; ſilex 24.; it ought to be conſidered as a native ſaturated alum, with exceſs of earth and deficiency of alkali, intimately mixed with ſilex and inflammable matter. The action of the fire in the roaſting is to drive off the inflammable matter, and from the ſweet aluminous taſte which is thus communicated to the ore, notwithſtanding the loſs by volatilization of part of its ſulphuric acid, it ſeems alſo to effect a ſeparation between the alum and the exceſs of earth. The ſubſequent cracking and breaking down upon expoſure to the air and moiſture, is probably cauſed by the abſorption of water of cryſtallization.

But though a conſiderable proportion of alum is thus obtained, without the addition of potaſh, it may be worth while to enquire whether a larger quantity might not be procured by a trifling additional expence. The alum of La Tolfa contains by Vauquelin's analyſis

49.	ſulphat of alumine
7.	ſulphat of potaſh
44.	water
100	

And according to Kirwan, (on the proportion of real acid, &c. 1799,) 100 parts ſulphat of potaſh are compoſed of 54.8 potaſh and 45.2 ſulphuric acid; and 100 parts alum of 63.75 alumine and 36.25 ſulphuric acid. Therefore, the 25 parts ſulphuric acid in the ore require 37.1 alumine and 4.5 potaſh. But the ore only contains at moſt 3.08 potaſh, ſo that no more than 16 parts of ſulphuric acid will be converted into alum; the remaining 9. will be left in combination with alumine in the mother water; and this agrees with the obſervation of Mazeas, who ſpeaks of an unctuous acid, efflorеſcent ſalt being left in the reſidue of the lixiviated ore. The 9 parts of acid that are thus loſt, may, however, be converted into alum, by the addition of 1.42 potaſh, or about 3. ſulphat of potaſh.

From theſe data the ore of La Tolfa ought to yield by the preſent method of working it 78.5 per cent. of cryſtallized alum; or by the addition of 3 per cent. ſulphat of potaſh, 125 per cent. of cryſtallized alum. In this calculation, however, no allowance has been made for the ſulphuric acid volatilized in the roaſting, and that portion of the ſalt which cannot be extracted by lixiviation in the large way from the prepared ore; both theſe circumſtances will, no doubt, diminiſh conſiderably the produce of alum, but the proportions muſt vary much according to the ſkill and attention of the manufacturer.

§ 4. *Manufacture of Alum from the Pyritous ores.*

All the European alum, except what is manufactured at Solfatara and La Tolfa, as deſcribed in the preceding ſections, is prepared from the alum ſlate or alum earth, and theſe containing only the remote principles of this ſalt, a much more complicated proceſs is required than where the alum exiſts ready formed in the ore.

The only neceſſary ingredients in the pyrito-aluminous ores are clay, and pyrites, or ſulphuret of iron. Beſides theſe, however, there is generally a variable proportion of bitumen, lime, and magneſia. The beſt alum is procured from the black micaceous ſpecies in which the pyrites is thoroughly diſſeminated through the maſs in ſuch ſmall particles as to be indiſtinguiſhable from the reſt. Such, however, as contains even large nodules of pyrites, is very capable of being manufactured, much of the Swediſh ore being of this kind.

The firſt thing to be done is to diſpoſe the pyrites to decompoſe into ſulphat of iron, (green vitriol), and this at the manufacture of Flone, in the department of Ourte, in France, is brought about by ſimple expoſure of the ore to the action of air and moiſture; this ore, however, is of the very beſt kind, moderately ſoft, free from bitumen, and with the ingredients well mixed, and even with theſe advantages, the proceſs requires three years. The more ſtony and bituminous kinds, ſuch as thoſe of England and Sweden, are ſubjected to a previous roaſting. For this purpoſe a layer of billet wood or coals is placed on a floor of rammed clay, and ſet fire to; upon this are thrown by degrees moderately ſmall pieces of unburnt ore, till a ſtratum is formed, about half a foot in thickneſs; theſe preſently take fire, by their own bitumen, and are then covered with a ſtratum of nearly the ſame thickneſs of ore that has been already roaſted and lixiviated; to this ſucceeds a layer of unburnt ore, and thus alternate layers, eight or nine in number, are gradually added, till the pile is completed. Care is taken by protecting it from heavy rains, and covering thoſe parts expoſed to the wind, to keep up the heat of a moderate equable degree till the bitumen being conſumed, the fire goes out of itſelf. If the ore is now examined it will be found to be of a reddiſh colour, containing a ſmall quantity of ſulphated iron and

alumine, and in ſome of the Swediſh manufactories is accordingly lixiviated without any further preparation. In the Engliſh and German alum-works, however, the roaſted ore is watered lightly, and expoſed for a greater or leſs time to the action of the air, by which the ſulphur of the pyrites is more completely oxygenated, and in conſequence a larger proportion of alum is obtained. In the manufactory of Flone, already mentioned, the ſingularly judicious practice is obſerved, of lightly roaſting the ore *after* ſpontaneous efflorеſcence.

The acid being thus developed, and in part united to the alumine, the proceſs of lixiviation takes place. For this purpoſe the ore is thrown into large reſervoirs of ſtone or wood, furniſhed with a falſe bottom, to ſerve the purpoſe of a filter; water is then poured on, and remains for twenty-four hours or more, in which time it diſſolves the greater part of the ſalts; this being let out by means of a cock fixed nearly level with the bottom of the reſervoir, a freſh quantity of water is added, in order to exhauſt the ore of all ſoluble matter. The ſecond lixivium is weaker than the firſt, but is afterwards concentrated by being uſed inſtead of water for the firſt lixiviation of the next parcel of ore. The water with which the lixiviation is performed is cold, and it might ſeem at firſt to be an obvious improvement to make uſe of boiling water; the experiment has, however, been tried without the deſired reſult, the increaſed ſtrength of the lixivium not being adequate to the time and expence of fuel. Where the lixivium is kept in large reſervoirs, expoſed to the weather, much depends on the dryneſs of the ſeaſon, a few heavy rains weakening the liquor to ſuch a degree, as to add conſiderably to the coſt of boiling down. In Sweden and the northern countries, various attempts have been made to concentrate the liquor by freezing, but the ſucceſs has not anſwered expectation; for a ſaturated ſolution of alum congeals at nearly the ſame temperature with common water.

The proceſs of boiling down ſucceeds to that of lixiviation, and is always performed in leaden boilers, copper being for the moſt part too dear a material, and iron being attended with the inconvenience of decompoſing alum. The lixivium is mixed in the boiler with the mother-water of a preceding boiling, and this is done either by filling the boiler with a mixture of mother water and liquor, and ſupplying the loſs by evaporation with freſh liquor, or by filling the boiler at firſt with liquor, and ſupplying the waſte by the above mixture. The evaporation laſts from twenty-four to forty-eight hours, according to the proportion of mother-water. In Saxony, where the proportion of mother-water is large, and the lixivium is brought to a high degree of concentration, the boiling continues without interruption for eight days. At the end of theſe reſpective periods the ſpecific gravity of the liquor is aſſayed by a leaden hydrometer, or, with greater exactneſs, by filling a bottle of known ſize with the liquor, and then, by weighing it, to aſcertain the comparative ſpecific gravity between it and water. This being done, an alkaline ſolution is added, and the firſt cryſtallization is brought about. In the Saxon manufactories, where the liquor is uncommonly concentrated, as ſoon as the evaporation is finiſhed the contents of the boiler are let out into a reſervoir, where they are ſtrongly agitated for half an hour, during which time a certain proportion of ſoap-makers lees and putrefied urine is added; and the liquor being then let into another vat, the cryſtals of alum begin immediately to be depoſited; at the end of a few days the mother-water is laded out, and the cryſtals are collected and waſhed. The method followed in the Engliſh works differs ſomewhat from the Saxon practice; in theſe when the liquor appears by the hydrometer to be ſufficiently evaporated, the fire is withdrawn from the boiler, and a ſtream of impure alkaline lixivium, from kelp and ſoap-maker's aſhes, is let into the liquor already in the boiler; at the ſame time the cock at the bottom of the boiler is turned, ſo as to allow the contents of it to flow into a reſervoir, by which management the two liquors are ſpeedily and effectually mixed. It remains in this reſervoir for three hours, during which it depoſits an earthy and ferruginous ſediment by the action of the alkali, and becomes of a clearer colour; it is now transferred into another large vat, and has its ſpecific gravity again taken, according to which a greater or leſs quantity of putrid urine is added to lower it to the proper ſtandard; being then agitated briſkly for a quarter of an hour it is left at reſt, and in the courſe of five days the cryſtals are depoſited. In ſome French and Swediſh manufactories the liquor, after being boiled down, is merely agitated for ſome time without adding any alkali, and then paſſed into the cryſtallizing tub. The rough alum being waſhed in order to ſeparate it from the green vitriol which is depoſited along with it, is put into a ſmall pan with a little water, and when diſſolved and boiling hot, ſome bullocks blood, or other ſimilar ſubſtance, is uſually added for the purpoſe of clarification: when this is effected, the liquor is run into caſks, where the cryſtals are depoſited in large maſſes; after ten or twelve days the mother-water is poured out, and the ſalt, being then dried, is ready for ſale. By keeping in mind the analyſis and experiments in § 1. of this article, it is eaſy to underſtand the *rationale* of the manufacture, as well as the advantages and faults of each proceſs. As ſoon as the pyrites is converted into ſulphat of iron, whether by roaſting or by ſpontaneous efflorеſcence, it begins to be gradually decompoſed by the lime and magneſia that may happen to be in the ore, therefore the leſs there is of theſe two earths, the greater *cæteris paribus* will be the produce of alum. Clay is incapable of decompoſing ſulphat of iron; but by expoſure to the air, eſpecially when aſſiſted by the action of heat, the metal becomes highly oxygenated, and is no longer combinable with the acid which then unites with the clay, as being the ſubſtance in the ore of next affinity. Hence ariſes the advantage of the practice at Flone of roaſting the ore *after* the formation of the ſulphat of iron. We have already ſeen in § 1. that ſulphat of alumine, even with exceſs of earth, is ſoluble in water, but that it becomes inſoluble on the addition of potaſh; on this account, therefore, coal, which contains little or no potaſh, is a far preferable fuel for roaſting the ore than wood which yields a great deal, as all the alum, thus rendered incapable of extraction by lixiviation, is loſt. The bitumen in the ore, however, diminiſhes the conſumption of wood, and the lixivium conſiſts of the ſulphats of iron, of alumine, of lime, and magneſia. By long boiling and evaporation the iron becomes ſo far oxygenated, that the addition of an alkali will decompoſe the ſulphat of iron, rather than the ſulphat of alumine. If the alkali is ever ſo little in exceſs, the aluminous ſulphat will be the next decompoſed; this is therefore to be carefully avoided. Nor is the kind of alkali a matter of indifference, for ſince only ammonia and potaſh are capable of forming cryſtallizable alum, it would appear that the uſe of ſoda in the Engliſh manufactories might be advantageouſly ſuperſeded by potaſh; indeed the chief uſe of the kelp ſeems to conſiſt in the potaſh which this impure ſoda contains. The principal thing to be attended to in the boiling down is to bring the liquor to ſuch a degree of concentration, that the alum ſhall be depoſited with as little as poſſible of the other ſalts.

The mother-water, when thrown away, holds in ſolution ſulphats of potaſh or ſoda, and ſulphat of magneſia, the extraction of which was made the ſubject of one of Lord Dun-

donald's patents, but we believe the profits have not yet anſwered the expence.

The nature of alum, and conſequently the true theory of its manufacture, has only been known ſince the publication of Vauquelin's excellent memoir on the ſubject in the Annales de Chimie; it is not ſurpriſing, therefore, that all the long-eſtabliſhed proceſſes ſhould be more or leſs defective. Perhaps the following method would be found to combine more advantages, and be ſubject to fewer inconveniences than any which has been hitherto put into practice. The ore ſhould be firſt ſlightly roaſted with coal to drive off the bitumen, and forward the decompoſition of the pyrites, which may be further accelerated by moderate waterings, and expoſure of freſh ſurfaces to the action of the air. When ſaline efflorefcences appear at the top of the heaps of ore, and their interior, upon being dug into, alſo ſeems penetrated with white ſaline particles, let the ore be diſpoſed in alternate ſtrata with coal, and again roaſted, ſo as to decompoſe as much as poſſible of the ſulphated iron, and combine the acid with the clay; the ſlower and more gently this proceſs can be carried on, the more completely will its object be anſwered. The lixivium obtained from this roaſted ore will conſiſt chiefly of ſulphated alumine, nearly ſaturated with earth, but, on account of the abſence of potaſh, perfectly ſoluble. By the ſubſequent boiling and agitation, part of the ſulphat of iron would be decompoſed, and this oxydation of the iron might perhaps be ſtill further effected, by pouring the liquor through heaps of faggots, expoſed to the wind, as is done in the *houſes of graduation* for brine in France and Germany. The ferruginous and ſelenitic ſediments being now allowed to ſettle, the clear liquor ought to be transferred into another reſervoir, and there mixed with a hot ſolution of acidulous ſulphat of potaſh, ſuch as remains after the diſtillation of aquafortis from nitre and ſulphuric acid; cryſtals will be immediately depoſited of an alum much purer than common; and theſe, by a further clarification, may be made equal to that of La Tolfa.

§ 5. *Manufacture of Alum by Chaptal's proceſs.*

An attempt had been made, but with little ſucceſs, at the manufactory of Javelle near Paris, to prepare alum by the direct combination of its conſtituent principles; but it was not till the admirable and deciſive experiments, in the large way, by Chaptal, publiſhed by him in the genuine ſpirit of philoſophic liberality, that the practicability of this method could be ſaid to be eſtabliſhed. According to the modern way of preparing SULPHURIC ACID, the requiſite proportions of ſulphur and nitre being mixed together, are brought to combuſtion in a cloſed chamber lined with lead; the ſulphur is thus acidified and converted into vapour, which by degrees unites with the water that overſpreads the floor of the chamber, and forms a liquid, diluted, ſulphuric acid. A ſimilar proceſs was inſtituted by Chaptal, only ſubſtituting dried clay for the water; the reſult of which was ſo favourable, that a large manufactory on the ſame plan was ſet on foot; which, having continued in full activity for ſeveral years, and producing alum only inferior to that of La Tolfa, merits a particular deſcription.

The chamber in which the combuſtion is performed is 91 feet long, 48 feet wide, and 31 feet in height to the pitch of the roof. The walls are of common maſonry, lined with a moderately thick coating of white plaſter; the floor is a pavement of bricks, ſet in a mortar, compoſed of baked and unbaked clay; and this firſt pavement is covered by a ſecond, in which the bricks are made to overlie the joints of the lower ones, and are themſelves firmly connected to each other by a cement, compoſed of equal parts of pitch, turpentine, and wax, made boiling hot, and poured between the joints inſtead of mortar. The roof is of wood, and the beams are ſet at much leſs diſtances than common; they are alſo channelled with deep longitudinal grooves, for the purpoſe of receiving the planks that fill up the ſpace between the beams; ſo that the whole of this great area of carpentry does not preſent a ſingle nail. The chamber thus conſtructed was covered on the ſides and top with a layer of the cement juſt mentioned, applied as hot as poſſible ſo as to penetrate into all the pores of the wood and plaſter; three more ſucceſſive layers were then laid on, and the laſt was poliſhed ſo as to preſent an uniform, even, ſolid face. In order to prevent the wood-work of the cieling from warping, it was covered on the outſide with a thick coating of cement, and a light roof of tiles was laid over the whole. By ſubſtituting this cement for a lining of lead, a vaſt ſaving was effected in the firſt expence; and it has been found, by long experience, to require much fewer repairs than even lead itſelf.

The clay ought to be of the pureſt kind, ſuch as pipe-clay; that it may contain neither lime nor magneſia, and as little as poſſible of iron. It is to be tempered with water, and made into balls five or ſix inches in diameter; theſe being dried in the ſun, are afterwards calcined in a furnace; the firſt effect of the heat is to blacken them, but ſoon after they become red hot, the carbonaceous matter which cauſes the blackneſs is burnt out. Being thus withdrawn from the fire and cooled, they are broken down into ſmall fragments, and ſpread on the floor of the chamber. In this ſtate they are expoſed to the vapour of ſulphuric acid from the combuſtion of ſulphur and nitre; and in a few days the pieces are obſerved to crack and open, and to be penetrated with ſlender ſaline cryſtals. The earth being at length covered with efflorefcences, it is removed from the chamber, and expoſed to the air under ſhelter of a ſhed, that the acid may obtain its higheſt degree of oxygenation, and become thoroughly united with the earth. It is now lixiviated, and the liquor contains, in ſolution, little elſe than acidulous ſulphat of alumine: this being boiled down to the proper conſiſtence, a ſolution of ſulphated potaſh (being the reſidue in the pots of combuſtion from which the ſulphuric acid was produced in the chamber, and conſiſting of the alkaline baſe of the nitre combined with ſome of the ſulphuric acid) is poured in, and the liquor being then transferred into a large vat, perfect cryſtals of alum are ſhortly depoſited, which are afterwards refined in the uſual manner.

The advantages of this proceſs are numerous. It may be carried on whenever a ſupply of proper clay can be had. The ſpace taken up by the works is much leſs extenſive than what is required according to the common methods. The whole manufacture is performed in at moſt one-third of the time uſually neceſſary. A large quantity of fuel is ſaved. The extraneous ſalts in the mother-water are fewer; an important uſe is made of the reſidual ſulphat of potaſh; and laſtly, the alum itſelf is much purer, and almoſt equally well adapted to fix the delicate dyes as that of La Tolfa, the commercial price of which is generally about double that of the Engliſh alum.

§ 6. *Brunſwick Alum.*

The dilute red colour of the roch alum, and the fleſh-coloured efflorefcences with which its cryſtals are covered, being its diſtinguiſhing character among the merchants, occaſioned two brothers of the name of Gravenhorſt to manufacture, ſome years ago, a ſpurious imitation of it at Brunſwick. We know not whether the manufacture is ſtill carried on or not; but if it is, the public will be benefited by the communication of an eaſy method of detecting the counterfeit, more

especially as the roch alum is the kind used in medicine, and the Brunswick imitation of it contains *arsenic*. The external appearance of the two sorts differs but little. The taste of the Brunswick alum is less styptic than that of the roch alum, it is less soluble in water, and when heated to redness, it loses only 37.5 per cent. of its original weight, while the other loses 50 per cent. The roch alum, when exposed to the blow-pipe, becomes opaque, swells, foams, and is converted into a spungy white mass. The Brunswick alum, on the contrary, swells less, scarcely foams at all, but melts, and becomes of a green colour, exhaling at the same time an arsenical vapour. Again, the precipitate from a solution of roch alum by potash or soda, being mixed with borax, fuses before the blow-pipe into a white or yellowish white; whereas the Brunswick, by the same treatment, affords a violet-coloured globule: and in fact it is nothing more than common alum, containing a little cobalt and arsenic.

§ 7. *Comparison of English, Roman, Levant, and French Alum.*

The Roman alum, manufactured at La Tolfa, is the purest and dearest of all; it is in pieces about the size of a walnut, shewing more or less of its crystalline form, and is opaque, on account of a farinaceous efflorescence with which it is covered. The Levant or roch alum appears in fragments of nearly the same size as the former, but in which the crystalline form is more obscure; it is externally of a dirty rose-colour, and internally exhibits the same tinge, but clearer. Smyrna is the place whence it is usually shipped for Europe; but it was anciently made at Roccha, or Edessa, in Syria, whence its commercial name roch-alum. The French alum, that is, Chaptal's, described in § 5. is in small, clear, colourless crystals. The English is in large, irregular masses, considerably harder than the others. Equal portions of all these kinds, being exposed in a muffle to a red heat, were weighed after the intumescence was over, and the loss by calcination in the Roman alum was 50 per cent.; in the Levant alum 40 per cent.; in the French alum 57 per cent.; and in the English 47 per cent. Of pure water, at 114° Fahr. Roman alum required 14 times its weight for solution; Levant alum required 12 parts; French alum 13 parts; and English 15 parts.

Equal parts of these four kinds of alum being dissolved separately in water, the same quantity of prussiated lime was added to each solution. That of the English alum became slightly blue at the end of a few minutes, as was also that of the French alum, though the tint was rather lighter; after some time the Roman alum became faintly blue; but the solution of Levant alum was only lightly yellow, the natural colour of the prussiated lime. After two days an inappreciable quantity of blue precipitate was deposited from the English alum, rather less from the Roman and French, and only a few atoms from the Levantine; the three first solutions were of a bluish green tint, but the last was a very dilute yellow.

Equal parts of the four sorts were dissolved separately in pure water, and their earthy base was precipitated by an excess of ammonia. The precipitate from the Roman alum was of a pure dead white; that of the Levantine and French was nearly equal to the Roman; but that of the English was of a just perceptible blush tint. By calcination in a red heat, they all at first became blackish, and ended with being perfectly white.

Hence is apparent the superiority of the Roman alum, and the inferiority of the English, when used as mordants for the most delicate colours: for other colours, and for the various uses besides to which alum is applied, each kind may be used indifferently. The English possesses less water of crystallization than the Roman or French; and a given weight of it will go further than the same quantity of any of the rest, as 12 per cent. is to be deducted from the Levantine, on account of the reddish insoluble sediment with which it is contaminated.

§ 8. *Historical notice of the introduction of alum-making into Europe.*

The ancients appear to have been acquainted only with the native plume alum, which they procured from Lipari, and the neighbouring volcanic islands. In the 12th, 13th, and 14th centuries it was manufactured at Edessa (Roccha) in Syria, in the vicinity of Constantinople, and at Phocæa (Foya nova), not far from Smyrna. Bartholomew Perdix, a Genoese merchant, who had often visited Roccha, discovered, about the year 1459, a vein of alum ore in the island Ischia, and there established the first European manufactory of alum; soon after John de Castro discovered the body of ore at La Tolfa. Establishments were then made at Viterbo, Volaterra, and other places in Italy, with such success, as induced Pope Pius II. to prohibit the importation of Oriental alum. In the 16th century this art was introduced into Germany and Spain; and a little before its conclusion the English alum-works at Whitby were instituted by Sir Thomas Chaloner, who had the honour of being personally excommunicated by the reigning pope on this very account. The earliest of the Swedish works dates no higher than 1637. Macquer's Chymisches wörterbuch von Leonhardi, art. Alaun. Annales de Chimie, vols. viii. xiv. xxii. xxix. Plinii. Hist. Nat. lib. xxxv. c. 52. Bergman's Essays, vol. i. Memoires de l'Acad. Royale, vol. v. Encyclopedie Method. art. Alun.

Alum, in *Chemistry, Materia Medica*, &c. See Sulphat *of Alumine*.

ALUMINE.—Pure earth of alum.—Pure clayey or argillaceous earth. *Alumine,—Terre d'alun.—Terre argilleuse*, Fr.—*Thon-erde*, Germ.

The word alumine has been adopted, without alteration, from the modern French nomenclature, by the majority of English chemists, as the technical name of pure argillaceous earth, on account of its being generally procured by the decomposition of alum, when required to be in a state of extreme purity.

Next to silex and lime, alumine appears to be the most commonly occurring earth in those stony or earthy masses, of which the globe, as far as we are acquainted with it, is principally composed. It forms the essential, though seldom the greatest part of all kinds of clays, giving to them the property of ductility or plasticity when mixed with water. When in a state of more intimate combination with silex it loses its quality of plasticity, and gives to the minerals in which it enters, the characters of opacity, of hardness inferior to that required for striking fire with steel, of that odour known by mineralogists under the name of earthy, and of that absence of crystalline form which is called amorphous; such are the immense masses of slate and argillaceous schistus that abound in almost all mountainous tracts, the boles, the colorific earths, the toadstones and clay porphyries. Alumine, however, occasionally, though very rarely, enters in large proportion into crystallized minerals, and then in its external characters of hardness, transparency and lustre, approaches very nearly to silex: such is the adamantine spar, inferior only in hardness to the diamond, and which contains from 80 to 90 per cent. of alumine: such also is the sapphire, which by the analysis of Klaproth appears to contain no less than 98 per cent. of

pure alumine. These, however, which are more properly the mineralogical than chemical characters of alumine, will be treated of more at large in the subsequent mineralogical articles.

Pure alumine, in a state proper for chemical experiment, has hitherto never been found native, and it is only of late that chemists have discovered the method of obtaining this earth sufficiently free from foreign admixture. The method of Bergman and his contemporaries was to decompose a solution of purified crystals of alum by an excess of carbonated potash, or soda, and to wash the earthy precipitate in repeated quantities of distilled water, till it came off perfectly tasteless and pure; a white uniform soft matter was thus obtained, which was supposed to be carbonated alumine, and this by drying in a heat below that of redness, was deprived of its acid and water, and was then esteemed pure alumine. The insufficiency of this method had begun to be suspected for some time, however, particularly from the appearance of sulphurated hydrogen, when alumine thus purified was heated with charcoal, and afterwards moistened with a diluted acid, and the admirable memoir of Vauquelin on alum, (which has already been referred to under that article) not only established the validity of these suspicions, but pointed out the method of avoiding the errors of his predecessors, and thus introduced a very important improvement in the difficult art of chemical analysis. Alum has already been shewn to be a triple compound of alumine, potash and sulphuric acid in excess, and when this excess of acid is taken away, either by the addition of alumine or of an alkali, an insoluble salt is produced differing from alum only in the proportion of its earthy base; now the ease with which a salt is decomposed depends very materially on its solubility, when, therefore, we add gradually to a solution of alum a solution of carbonated alkali, the first effect is to neutralize the excess of acid, and the precipitate consists principally of the insoluble salt just mentioned; a further quantity of alkali, especially if assisted by heat, will effect the decomposition of part of the salt, but in proportion as this takes place the residue becomes mixed with the alumine, and thus is covered from the further action of the alkali. This being the case, it is obvious that no subsequent washings can do more than separate the sulphated potash; and therefore the residue, instead of being pure alumine, contains besides a variable proportion of earthy alum, from which last proceeds the sulphur observable on heating it in a close vessel with charcoal.

The only way by which alum can be made to yield its earth in a state of sufficient purity for delicate chemical experiments, is the following. Take any quantity of Roman alum, and dissolve it in lukewarm distilled water, filter the solution, and set it to crystallize. When by cooling and spontaneous evaporation, a sufficient portion of this purified alum is deposited, take it out and redissolve in cold distilled water; to this solution add liquid caustic ammonia, a white precipitate will be thrown down, and continue the gradual addition of ammonia till no farther precipitation takes place; heat the liquor then nearly to boiling for a few minutes, add more water, and throw the whole on a paper filter; in proportion as the fluid drains off add water, till it passes through quite tasteless. The precipitate, while yet in a pulpy state, is to be removed into a flask, and digested with muriatic acid till it is dissolved. The muriatic solution being then concentrated by very gentle evaporation, will at length deposit crystals of alum, which are to be removed, and this process is to be continued till the liquor ceases to yield any more. Nothing now but pure alumine remains in the solution, the potash and sulphuric acid being got rid of, at the expence of a little of the alumine in the crystals, the liquor is therefore to be diluted with water; and ammonia fully sufficient for the decomposition of the muriated alumine being then added, the process of filtration and edulcoration is to be gone through as before, and the result will be pure alumine. On account of the length of this method, and the possibility that even after all a very minute proportion of sulphated potash may still remain, it has been the practice of late with Vauquelin and Berthollet to procure their pure alumine from such of the natural clays as contain only silex and alumine, by digestion in muriatic acid and decomposition of the solution by ammonia.

Pure alumine, obtained by the above methods, is opaque, of a snow white colour, a smooth somewhat unctuous feel, has no smell, even when breathed upon, or moistened with warm water, nor any proper taste; when placed upon the tongue, however, it absorbs all the moisture with which it finds itself in contact, and thus occasions a peculiar sensation of astringency. It is readily diffusible, and remains for a long time suspended in water, but appears to be totally insoluble in this fluid. Its specific gravity is variously estimated, according to the degree of desiccation, by Bergman it is reckoned 1.305, while Kirwan allows it as much as 2.0. After being thoroughly dried in a heat just not sufficient to destroy its plasticity, it is capable of absorbing 2½ times its weight of water, without allowing any to drop out, and the water thus mixed is retained more obstinately at the usual atmospheric temperature by alumine than by any other earth; a freezing cold however causes this earth to contract remarkably, and thus squeeze out a large proportion of its water.

Alumine is the only earth that possesses the property of plasticity, or of being kneaded up with water into a soft ductile paste, capable of being formed by the hand or the potter's wheel into any shape that may be required; the plasticity therefore of all the natural clays is owing to their aluminous part; nor is this property destroyed even by a very large admixture of other earths; in the finer kinds of pottery scarcely a fourth of the whole mass is pure alumine, and yet its plasticity is unimpaired. If a piece of tempered clay is dried gently in the air, it retains its form, but becomes quite brittle; its former ductility may, however, be restored by again kneading it with water. If exposed to a red heat it hardens, contracts in all its dimensions, becomes more compact, and of greater specific gravity, and is no longer plastic, nor can this property be restored to it by any other means than by solution and precipitation; hence bricks or pottery ware, after having been baked, if pounded ever so fine, are no more capable of forming a paste with water.

The action of caloric on alumine is accompanied by some interesting phenomena which deserve mentioning. If the purest plastic alumine is exposed to a low red heat, it becomes of a bluish black colour, especially on the inside, as is manifest by breaking a piece across that has been thus heated; as soon as this colour is perceived the plasticity is destroyed, a fact that renders it probable that this property of alumine depends on something else than mere water. By a further increase of the heat with access of air, the carbonaceous colouring matter is burnt out, and the alumine acquires a resplendent white colour, becoming at the same time harder, denser, and of less bulk: all these changes advance in gradual progression in proportion to the heat; and after it has thus experienced the full effect of our most powerful furnaces, it will be found to be so hard as to give fire with steel, and reduced to nearly one half of its original bulk. Upon this last property is founded the use of *Wedgewood's* PYROMETER, for measuring the higher degrees of heat. The

decreafe of bulk is in part occafioned by the expulfion of the laft particles of water; but from the augmented fpecific gravity of the alumine, it is plain that an actual condenfation or approximation of moleculæ takes place, as is obfervable in various other porous fubftances previous to fufion. Whether any artificial heat is able to bring this earth into real fufion is as yet dubious; for though Lavoifier, by means of a blow-pipe charged with oxygen gas, reduced a piece of alumine to a pafty femi-fluid ftate, yet it is probable, as the earth was obtained from alum, that a minute portion of potafh might ftill be contained in it, and thus act as a flux.

Alumine has a ftrong affinity for metallic oxyds, efpecially the oxyd of iron; hence arifes the difficulty, and indeed almoft impoffibility, of obtaining alum free from iron in the great way, becaufe all natural clays and aluminous ores contain more or lefs of this metal. The only way of accurately feparating thefe two fubftances is by digeftion in cauftic potafh or foda, which will diffolve the earth but not the oxyd.

Thefe two fubftances are alfo capable of acting on each other in the dry way at high temperatures; and fome important experiments on this fubject are recorded by Achard and Kirwan, from which it appears, that when the proportion of alumine exceeds that of the oxyd of iron, the mixture is in all cafes very difficultly fufible; that when the proportions of the ingredients are equal, and efpecially when the iron predominates, the refult, after expofure to a heat of about 160° Wedgewood, is a dark-coloured vitreous flag.

The attraction too that fubfifts between alumine and vegetable or animal colouring matter, is fingularly powerful. Thus, if, to a watery infufion of cochineal or madder, a few drops of a folution of alum are added, a decompofition fhortly takes place, and the whole of the tinging particles unite, and are precipitated together with the aluminous bafe of the earthy falt, leaving the fupernatant liquor wholly colourlefs. Fugitive colours alfo, by this combination, become of fufficient permanence to refift for a long time the changes to which they are fubject: hence is explained the preparation of the LAKE *pigments*, and the theory of Mordants in the art of DYING.

In the direct way fulphur appears to contract no union with alumine; and the hepatic gas that is feparated by an acid from alum, after having been heated with charcoal, is no longer a decifive evidence of fulphuret of alumine, fince the difcovery of the neceffity of potafh to the very conftitution of common alum.

Upon the gafeous fubftances alumine has not been obferved to produce any change, although Humboldt has publifhed (Annales de Chemie, vol. xxix.) a long and plaufible memoir, to fhew that alumine abforbs the oxygen of the atmofphere, and hence produces an important effect in the economy of vegetation. It is true, indeed, that many natural clays will deoxygenate atmofpheric air; but this is folely owing to the carbonaceous matter, and oxyd of iron that they contain, it having been proved by accurate experiments, inftituted for this purpofe by Theod. Sauffure and others, that pure alumine has no effect whatever on oxygen gas or atmofpheric air.

All the acids are capable in particular circumftances, of combining with alumine; but thefe combinations are not accomplifhed with the fame eafe as thofe between the acids and alkaline earths. The ftronger mineral acids will take up alumine from clay by digeftion at a boiling heat, but the vegetable and other weaker acids will not readily effect a folution, except the alumine is prefented to them recently precipitated by an alkali from fulphuric, nitric, or muriatic acid. All the aluminous falts are decompofed with precipitation of the earth by the cauftic or carbonated alkalies, or alkaline earths. For further particulars fee the falts under their refpective acids.

Ammonia has not yet been obferved to exert any action on pure aluminous earth; but both potafh and foda, when cauftic, will diffolve it without any difficulty. This may be done by evaporating to drynefs, and igniting in a filver crucible, a mixture of cauftic alkali and alumine, and then lixiviating the mafs, or merely by boiling fome frefh precipitated alumine in a watery folution of the alkali. This alkalized alumine has of late been recommended as a preferable mordant to common alum in the fixing of thofe colours that are injured by the prefence of fulphuric acid. To feparate alumine from its folution in cauftic alkali, it is neceffary to add nitric or muriatic acid in fufficient quantity to neutralize the alkali and diffolve the alumine, and then to precipitate the earth by cauftic ammonia.

The action of barytes on alumine is analogous to that of the alkalies, yet prefents fome peculiar characters. When a folution of cauftic barytes in water is added to a liquid muriat of alumine, the firft effect is the appearance of a precipitate, owing to the decompofition of the falt by the barytes; if this laft, however, is added in excefs, the alumine is rediffolved by it, and the liquor becomes clear.

Again, if equal parts of newly precipitated alumine and cauftic barytes are boiled together in a quantity of diftilled water fufficient to take up the barytes, about half the mixture will be diffolved, and upon analyfis the infoluble refidue will be found to confift of alumine, with a fmall proportion of barytes, while the folution will confift of much barytes and a little alumine. By adding to the liquor fome muriatic acid, to engage the excefs of barytes, a flocculent precipitate will be depofited, confifting of the two earths, nearly in the proportion of the original infoluble refidue. Hence it appears that alumine combines with barytes into a falt which is infoluble in mere water, but is capable of being rendered foluble therein by the affiftance of barytes. In the dry way, at about 150° Wedgewood, any mixtures of the two earths in which the alumine preponderates remain pulverulent; but when the barytes is three or four times as much as the alumine, the powder concretes into a hard mafs, without, however, fhewing any figns of fufion. In order to decompofe barytic alumine, diffolve the whole in muriatic acid, and add cauftic ammonia; the alumine alone will be precipitated.

Strontian produces the fame effect on alumine as barytes, but more feebly; the action of thefe two fubftances in the dry way, on each other, has not yet been the fubject of experiment.

It appears highly probable that lime has a fimilar affinity for alumine, as the reft of the alkaline earths poffefs; the only experiment, however, upon the fubject, is one of Morveau; he mixed equal parts of muriat of alumine and muriat of lime in folution, and immediately a precipitate took placed, which was infoluble by an excefs of acid; this has been fince repeated by Darracq, a pupil of Vauquelin, without effect, the liquor remaining perfectly limpid; hence it is probable that the alumine of Morveau was not quite free from fulphuric acid, and that the infoluble precipitate was merely felenite. In the dry way lime and alumine in any proportions are infufible, except by means of a blow-pipe, charged with oxygen gas.

The action of magnefia on alumine is not yet fully afcertained: it appears, however, from Mr. Chenevix's experiments, that the ammoniaco-magnefian triple falts, are formed with difficulty, when alumine is prefent, and that magnefia prevents, in a great meafure, the folubility of alumine in the cauftic fixed alkalies. This combination of the two

earths is, however, [illegible] in muriatic or nitric acids, and may then be decomposed either by hydrosulphuret of soda or of ammonia, which will precipitate the alumine and retain the magnesia in solution, or by an alkaline prussiat, which will also separate the alumine while the prussiated magnesia remains dissolved. In the dry way, according to Kirwan, magnesia and alumine at 150° Wedgewood have no action on each other in any proportions.

A considerable degree of affinity exists between silex and alumine, and the unsuspected formation of this compound in many analytical experiments on minerals has often produced a number of deceitful and embarrassing appearances, which have vitiated the results of many a laborious analysis. Chemistry is, therefore, indebted to Klaproth for shewing, that when to a solution of pure silex in caustic potash is added a solution of alumine equally pure in the same menstruum, the liquor immediately assumes a reddish brown colour; and after standing an hour or more, coagulates into a thick opaque whitish jelly. This jelly, by the addition of a little warm water, is resolved into a fluid, and being then mixed with muriatic acid, to the exact saturation of the alkali, a copious precipitate is deposited, consisting of the two earths, in a state of combination; if now a slight excess of acid is dropped in, the silex as well as the alumine, will be perfectly dissolved. Carbonated potash will again cause the precipitate to appear, and this even when separated by filtration and dried, will be still entirely soluble in dilute sulphuric acid, without the smallest deposition of silex. If the sulphuric solution is now gently evaporated, crystals of alum will be deposited, and the remainder will assume the form of a clear jelly, the surface of which, after a few days, will be covered with crystalline pyramids; and in order to shew that it is really silex mixed with alumine, which has thus repeatedly been dissolved in acids, nothing more is necessary than to mix this jelly with a large quantity of water, and digest it for some while in a moderate heat, stirring it repeatedly at the same time, when the liquor will become turbid and pure silex will be deposited. In the dry way, according to Kirwan, equal parts of alumine and silex at 160° Wedgewood concrete together, but shew no signs of fusion.

Alumine is as yet a pure chemical element, never having been composed or analysed. From its affinity with colouring matter, and its blackening in a low heat, Baron was of opinion that it was of a metallic nature, and even Lavoisier entertained the idea that it might be a metallic oxyd, whose component elements were united together by a very powerful affinity. Beaumè considers the earth of alum as essentially the same with silex, being led into this mistake by fusing rock crystal repeatedly with potash, and always obtaining alumine; this experiment of Beaumè was repeated by Scheele, who found indeed that it was true whenever an earthenware crucible was made use of, but perceiving the crucibles corroded internally after every process, he suspected that the alumine was furnished by the action of the alkali upon them; in proof of which he repeated the fusion of silex with potash in an iron crucible, and as might be expected, did not procure a particle of alumine.

The uses of pure alumine are wholly confined to the laboratory; it gives, however, their peculiar character to all clays; every thing, therefore, that depends on the cohesiveness and plasticity of these substances when fresh, and their hardness after being baked, may be fairly attributed to the alumine which they contain; hence, it is the basis and material of all the arts of pottery, from the common brick to the finest porcelain, and these include more of the comforts and elegancies of life than are perhaps dependent on any other substance in nature.

Journal de Physique, vol. lii.—Scheele's Essays.—Klaproth's Analytical Essays.—Kirwan's Mineralogy, vol. i.—Annales de Chimie, vols. xxviii. xxix. xxx. xl.—Macquer's Chemisches Worterbuch, vol. vi.—Beaumè Chymie Experimentale, vol. i.

Ammonia

AMMONIA, or VOLATILE ALKALI. Alkali volatile, *Ammoniaque*, Fr.—*Alkali fluchtiges; Harnſalz, urinſalz, fluchtiges*, Germ.

Under the article ALKALI we noticed ſome of the peculiar properties of the *volatile* alkali whereby it is diſtinguiſhed from the *fixed*. We ſhall, in this place, give a more particular account of ammonia, which requires conſiderable notice from its high importance as a chemical agent, and from the numerous reſearches which have been made into all its properties and combinations, with more ſucceſs than perhaps has fallen to the ſhare of any other ſubſtance of equal value to the chemiſt.

As ammonia is never found native in an uncombined ſtate, and is, in moſt caſes, a *product* of various natural or artificial proceſſes, we ſhall refer the reader to the articles ANIMAL matter, CARBONAT of ammonia, MURIAT of ammonia, and ſalt of HARTSHORN, for every thing that relates to the natural hiſtory of this alkali and its production in the large way as a manufacture, and ſhall here confine ourſelves to the purely chemical deſcription.

The volatile alkali (like ſo many other chemical agents) when perfectly pure and uncombined, is only known to us in the form of a gas; and, as it is the only one of the alkalies which is capable of aſſuming this form in any common degree of heat, the term *alkaline* air, uſed by Dr. Prieſtley and many other chemiſts, is ſynonymous with ammoniacal gas. This gas has the following properties: It poſſeſſes a moſt pungent ſmell, which, when ſtrongly ſnuffed up the noſtrils, provokes to coughing, and gives a temporary ſenſe of ſuffocation, owing to the conſtriction of the fauces which it produces. To the taſte it is highly ſtimulating and acrid, and quickly corrodes the ſkin of the tongue and lips, ſo that it cannot be taken into the mouth in the undiluted form with ſafety. It is ſpeedily fatal to animals that are immerſed in it, and it extinguiſhes a taper; but the flame of this laſt is firſt enlarged, and becomes of a pale yellow colour. Ammoniacal gas is, next to hydrogen, the lighteſt of all the gaſeous bodies. Its ſpecific

gravity may be reckoned about 0.735 (diftilled water being 1000.) whereas atmofpheric air is 1.23, or nearly twice as heavy as alkaline air. The abfolute weight of 100 cubic inches of this gas at 30° bar. and 61° therm. is reckoned by Kirwan to be 18.16 grains. It is highly dilatable by heat, and at a very high temperature is decompofed. It is alfo very rapidly and copioufly abforbed by moft liquids, efpecially by water, and hence it cannot be kept over water; but, for the purpofes of experiment, it muft be confined in well clofed bottles or over mercury.

Ammoniacal gas is given out during the diftillation of almoft every animal, and fome vegetable matters, but it cannot in this method be procured fufficiently pure for chemical experiments. For this purpofe the muriate of ammonia (or common crude fal ammoniac) is the moft convenient material for yielding the gas. This falt is readily decompofed by quicklime, which laft unites with the muriatic acid of the falt, and expels the ammonia in its pureft and moft cauftic form of gas. The decompofition is fo fpeedy, that a very pungent fmell of volatile alkali is perceived merely on rubbing together thefe two fubftances. If one part of dry fal-ammoniac is mixed with two parts of well burnt lime (or lefs if the lime is good), put into a dry phial or earthen tube, and heated gently, the ammoniacal gas rifes in great abundance, and may be directed by means of a bent tube under a jar full of dry mercury, where it may be preferved in the gafeous form for any length of time. Many of the metallic oxyds, efpecially minium or litharge, will fupply the place of the lime and expel the gas from the muriate of ammonia in very great purity. A ftill more fimple method of obtaining the gas is to apply a gentle heat to the liquid or watery folution of ammonia, which expels from it the alkaline air that the water had previoufly been made to abforb at a lower temperature. It may be remarked that the difcovery of ammonia in a gafeous form, as well as many of the moft interefting properties of this alkali, is due to Dr. Prieftley.

Ammonia, diffolved in water (forming the *liquid ammonia* of modern chemifts, the *fluor volatile alkali* of former times, or the *aqua ammoniæ puræ* of the London Pharmacopœia) is the form in which the cauftic ammonia is the moft familiar to us, and in which many of the properties of the alkali can be moft conveniently examined. This, when pure, fhould be perfectly tranfparent and colourlefs as water, fhould have the ftrong burning tafte and pungent fmell of ammonia, and fhould give no effervefcence with acids. This latter teft deferves attention on account of the variety of volatile alkaline liquors that are prepared, all of which, except the *aqua ammoniæ puræ*, contain more or lefs carbonic acid, and are much milder in all their fenfible properties.

Ammoniacal gas is abforbed by water with great rapidity, and at the fame time a confiderable quantity of heat is given out from the gas, which is fufficient to raife the temperature of the water, and to be fenfible to the hand. The fame gas, when put in contact with ice, melts it with apparently as much rapidity as if the ice were put into a fire, and is greedily abforbed, at the fame time that confiderable cold is produced. At a moderate temperature water may be made to diffolve nearly one third of its weight, or many hundred times its bulk, of this gas. The bulk of the water is fo much increafed by this procefs that it becomes fpecifically lighter than diftilled water. Mr. Davy, in his experiments on this fubject, (Refearches into nitrous Oxyd, 1800.) found that, at the temperature of 52°; 100 grains of liquid ammonia, holding in folution 9.502 grains of the alkali, gave a fpecific gravity of .9684. When *perfectly faturated*, 100 grains of the liquid alkali contained 25.37 grains of ammonia, which is full one-third of the weight of the water employed, and had the fpecific gravity of .9054. Other writers, however, make the fpecific gravity of faturated liquid ammonia as little as .897. The gentle heat of a fpirit lamp again expels the alkali in the form of gas, but the laft portions require a ftrong ebullition before they can be made to quit the water. When liquid ammonia is expofed to a very intenfe cold, fufficient to freeze mercury, as Meffrs. Fourcroy and Vauquelin have obferved, it becomes a grey femi-tranfparent mafs, of the confiftence of a very ftiff jelly, and with fcarcely any odour.

The liquid ammonia is prepared in two methods. That which is the oldeft and the moft ufually practifed, is to mix together quick-lime, muriate of ammonia, and water, and to diftil the mixture with a gentle heat. The London Pharmacopœia orders for the preparation of the pure liquid ammonia, two pounds of lime flacked in two pints of water, and one pound of fal ammoniac, which are to be mixed with fix pints of hot water, and to be kept in a covered veffel till cold. The liquor is then to be diftilled, and the firft pint which comes over is the pure liquid ammonia. This liquor, however, is by no means faturated with the alkali, for during the heat, even of a gentle diftillation, the folvent power of the water is much leffened. The moft elegant and effectual way of preparing this liquor is to difengage the gas from the *dry* materials; and by ufing the beautiful APPARATUS of Woulfe, to caufe the alkaline air to pafs into cold water where the abforption is much more fpeedy; and, if neceffary, the increafe of temperature produced by this abforption may be prevented by furrounding the bottles with ice. The proportions of the ingredients here ufed, may be two parts of lime flacked in as little water as poffible, mixed with one part of dry muriate of ammonia and put into a retort for the production of the gas; and, in the condenfing bottles, about as much water as the weight of the fal ammoniac employed. The liquid ammonia is known to be thoroughly faturated with the alkaline gas, when the bubbles pafs through the water undiminifhed, and no further abforption takes place.

Many of the combinations of ammonia with different chemical agents are highly curious and important; but as moft of them produce alterations which depend on the decompofition of this alkali, they will be better underftood by the reader, if we firft relate fome of the multitude of facts by which the analyfis of ammonia has been afcertained. The conftituent parts of the volatile alkali are, hydrogen (or the bafis of inflammable air), and azot (the bafis of phlogifticated air), the proportions of thefe two fubftances are, about 29, (in weight) of the former, and 121 of the latter; and it may be remarked that this is the only fimple combination of thefe two fubftances with which we are certainly acquainted. The proofs of this analyfis we fhall relate nearly in the order of difcovery by the various eminent chemifts who have thrown light on the fubject.

Dr. Prieftley was the firft who remarked a very interefting change produced on alkaline air by means of electricity. For this purpofe he confined a known portion of this gas in a jar over mercury, and paffed a number of fucceffive electric explofions and fparks. He found after every fhock that the bulk of the confined air increafed, and continued to do fo till it had expanded to nearly three times its original bulk. The air was now much altered in its properties, for on letting up fome water into the jar, fcarcely any of the gas was abforbed, whereas before electrization every par-

ticle of it would have rapidly united with this fluid. The gas was found to be highly inflammable, and exploded when mixed with common air, in the fame manner as the inflammable air procured from iron by an acid. The gas likewife after being a fhort time in contact with water had entirely loft its alkaline fmell. The colour of the electric fpark taken in the alkaline air was red, but white in the centre, when any confiderable explofion had been taken.

The fame eminent chemift likewife found alkaline air to be decompofed by paffing through a red hot tube, though not fo completely as by the electric fpark. In performing this experiment he found the tube, through which the alkaline vapour had paffed, lined with a black matter, and the liquor collected after this diftillation alfo obfcured with the fame fubftance. This is probably owing to fome fiffure in the tube which admitted carbonaceous matter from the hot coals, as we fhall mention hereafter. Another property of alkaline air, highly illuftrative of its compofition, is the reduction of feveral metallic oxyds which it effects when they are heated in contact with it. Dr. Prieftley confined fome litharge, or oxyd of lead, in this gas, and by heating it with a burning lens (a method of applying heat of all others the moft accurate), he revived the lead in its metallic form, and a quantity of phlogifticated air remained. The red mercurial oxyd, or *red precipitate*, was heated in the fame manner, and the mercury was revived, and at the fame time a confiderable quantity of *water* was produced fo as to run down in drops on the fides of the jar, which before appeared perfectly dry. The red precipitate, however, gave out during this reduction a large quantity of uncombined dephlogifticated air, which appeared in the refidual air after the reduction was completed. This, in another experiment with the fame materials, united with fome of the inflammable air contained in the alkaline gas and caufed a confiderable explofion. The antiphlogiftic theory will readily explain the production of *water* during the experiment from the union of the oxygen of the red precipitate, and the hydrogen of the ammoniacal gas; but this fact more properly belongs to the fubjects of WATER and PHLOGISTON.

Thefe experiments were foon repeated by various chemifts, and with fimilar refults. Landriani found, that in paffing ammoniacal gas through a tube heated white hot, the alkaline properties were entirely loft, inflammable air was produced, and likewife a fmall portion of carbonic acid fufficient to give a precipitate with lime water.

Van Marum, in his experiments on the effect of electricity on the gafes, found the fame refults with ammoniacal gas that we have juft mentioned. Two cubic inches and feven eighths of the alkaline gas were enlarged to four inches, and the air was no longer abforbed by water, and was highly inflammable.

Whilft the properties and compofition of the volatile alkali were made the fubject of fo much ingenious and fuccefsful refearch by Dr. Prieftley, they received full elucidation by the labours of one of the moft eminent of the French chemifts, M. Berthollet.

This excellent experimentalift found, that when the oxygenated marine acid is added to liquid ammonia perfectly cauftic, a confiderable effervefcence takes place, and a quantity of gas is collected from the two liquids, which, when examined by the ufual chemical tefts, proves to be pure azotic gas. At the fame time the oxygenated acid lofes its peculiar pungent fmell, and becomes converted into fimple marine acid. The explanation given of thefe phenomena is, that the ammonia is decompofed by the oxygenated acid; the hydrogen of the alkali unites with the excefs of oxygen contained in the acid, and forms water, which mingles with the acid; whilft the azot, the other conftituent part of the ammonia, appears uncombined in the form of gas. The gas was found by Berthollet to be azotic, both by the common methods of examination, and by its forming nitrous acid when united with oxygen by means of the electric fpark, in the method that Mr. Cavendifh had difcovered. The fame decompofition takes place if the oxy-muriatic acid and the ammonia are ufed in form of gas. See OXY-MURIATIC ACID.

This theory of the decompofition of ammonia was alfo beautifully illuftrated by the fame ingenious chemift, in his accurate and original experiments on the nature and preparation of fulminating gold. Thefe will be given more at length under the article GOLD; but it may be here mentioned that the fulminating compound is formed by precipitating a folution of gold in aqua regia by the volatile alkali. This precipitate confifts of the metal, of oxygen which it acquires during folution in the acid, and of a part of the ammonia employed to feparate it from its menftruum, which is retained by the metallic oxyd, and which gives it the property of exploding in a very gentle heat. M. Berthollet ventured to explode fmall and known quantities of this preparation in copper tubes, and found the products to be water and azotic gas and the oxyd of gold completely reduced. The ammonia therefore is here decompofed, its hydrogen produces water with the oxygen of the gold, and its azot is fet at liberty in the form of gas. Some other of the metals which have a weak affinity for oxygen are reduced to a reguline ftate by means of the volatile alkali, which is alfo decompofed in the procefs. M. Berthollet alfo repeated Dr. Prieftley's experiment of the analyfis of ammoniacal gas by electricity, taking every poffible precaution in order to enfure an accurate refult; and the calculations deduced from it have been very generally acquiefced in, and confirmed by fubfequent enquirers. For this purpofe he paffed a fucceffion of electric fparks through 1.7 cubic inches of ammoniacal gas till it acquired its utmoft degree of expanfion, when it occupied 3.3 cubic inches, a degree intermediate between the refults of Dr. Prieftley and M. Van Marum. A certain quantity of this enlarged gas was then detonated with a fuperabundance of oxygen gas in Volta's eudiometer, whereby water was produced and the azotic gas of the ammonia remained unaltered. Then (affuming the quantity of oxygen entering into the compofition of water to be to the hydrogen, as 74 to 145, according to the calculations of M. Monge, given in the Memoirs of the French Academy) M. Berthollet eftimates the proportions of the conftituent parts of ammonia to be 2.9, in *bulk*, of hydrogen, to 1.1 of azot, or, in *weight*, (affuming the hydrogen to be eleven times lighter than the azot) 150 grains of ammoniacal gas will contain 121 grains of azot, and 29 grains of hydrogen.—Journal de Phyfique for 1786.

The above are the principal facts which have been brought to prove the *decompofition* of ammonia. A number of others, equally important and curious, will throw light on the mode of its *formation* from the union of its conftituent parts.

An accidental production of ammonia in circumftances where it had not been expected had frequently been remarked by various chemifts. Dr. Prieftley, in his numerous experiments on nitrous air, found by accident that when iron filings had been long kept in a jar, and moiftened with a diluted folution of copper in the nitrous acid, a thick

faline red incruftation was formed, mixed with a green matter, which, when broken, had a ftrong fmell of volatile alkali. Repeating the experiment he found that the fame effect would be produced, though more flowly, by fimply allowing iron to ruft in nitrous air, when, after fome weeks, the fmell of volatile alkali plainly appeared. The nitrous gas likewife underwent a confiderable change, being diminifhed about one-third, and then fupporting combuftion in a high degree, which laft property was, however, loft by wafhing in water, and a large refiduum of phlogifticated air was left.

A production of ammonia, in fomewhat fimilar circumftances, is likewife particularly noticed by Mr. Hauffman of Colmar. (Journal de Phyfique for 1787.) He relates, that on mixing nitrous gas with phlogifticated precipitate of iron, a large quantity of the gas is abforbed, leaving only a fmall refidue of phlogifticated air; and on adding cauftic fixed alkali to the iron precipitate, a fmell of volatile alkali is very perceptible, and a ftraw moiftened with nitrous acid and held over the mixture alfo indicates the prefence of ammonia by forming denfe white fumes. Mr. Hauffman diftinguifhes accurately between the phlogifticated and the dephlogifticated folutions of iron, the former being formed by diffolving the metal in acetous acid, or in the vitriolic without previous preparation; and the latter being a folution in vitriolic acid of iron which has been previoufly precipitated from a nitrous folution, and is therefore fully dephlogifticated, or, as is now faid, in the higheft ftate of oxygenation. The fame chemift employed the folutions of iron in various ftates, and found, that wherever nitrous gas was abforbed by the iron, a certain quantity of ammonia is alfo produced, which, he alfo obferves, probably remains in union with the vitriolic acid till it is difplaced by cauftic fixed alkali. The properties of this compound of nitrous gas and oxyd of iron will be examined more particularly under the article EUDIOMETRY, as it is intimately connected with this fubject.

Still further light was thrown on the curious phenomenon of the production of ammonia, by fome interefting experiments of Dr. Auftin. (Philofoph. Tranfact. for 1788, vol. lxxviii.) The compofition of ammonia having been fully afcertained by the experiments of Prieftley, Berthollet and others, Dr. Auftin attempted to produce the alkali by a direct union of its conftituent parts. For this purpofe he mixed inflammable and phlogifticated airs in different proportions, and added to them fome of the acid airs in order to favour their combination, tried the effects of cold, of heat, of electricity; and laftly, he decompofed alkaline air, and endeavoured to reunite the identical parts, but in no inftance could he fucceed in forming ammonia from the conftituent parts of this alkali, *when both were employed in a gafeous form.*

Hydrogen and azot, however, are certainly the conftituent parts of ammonia, and their refufal to unite when in the form of gas led Dr. Auftin to vary his experiments by mixing thefe fubftances together in fuch a manner that the hydrogen fhould be involved in an atmofphere of azotic gas juft at the time when it was itfelf beginning to affume the gafeous form. This has with great propriety been termed the *nafcent ftate* of a gas, and this experiment was fuggefted to Dr. Auftin by another very ftriking production of ammonia from nitrous acid and tin, which we fhall prefently mention. He therefore inclofed in a glafs tube fome azotic or phlogifticated air, and along with it fome iron filings, moiftened with water, which laft were known to yield inflammable air after ftanding together for fome hours; and this air therefore in its nafcent ftate, or at the inftant of its formation, was in full contact with the azotic gas. To detect the minuteft quantity of ammonia he alfo inclofed in the tube fome paper ftained with the blue of the rind of the radifh, which is turned to green by alkalies. In twenty-four hours he found the colour entirely green. Another teft was alfo ufed to indicate the prefence of ammonia, which was paper ftained with a folution of nitrated copper; the green of which was, in a few days, converted to blue, the proper colour of a folution of copper in ammonia. Dr. Auftin found nitrous air to effect a much more fpeedy production of ammonia when ufed inftead of the azotic gas. Atmofpheric air will alfo fucceed, but requires a longer time than the azotic air, fo that ammonia fhould always be formed whenever iron in contact with water rufts in the open air. In this formation of ammonia by the direct combination of its principles, it is neceffary, as Dr. Auftin obferves, that the hydrogen fhould be only in the nafcent ftate when it comes in contact with the azot, for if it is already in the form of gas it cannot be made to unite with the azot in any form fo as to produce ammonia.

We may here remark, that this mode of effecting chemical union between bodies which, when uncombined, are only known in the gafeous form, (fuch as oxygen, hydrogen, and azot) by prefenting one to the other when in the nafcent ftate, fhould always be kept in mind in experiments of refearch, as it may be the means of very important difcoveries in this difficult part of experimental chemiftry. Mr. Kirwan, in his valuable experiments on hepatic air, obferved the formation of volatile alkali when this air was mixed with nitrous gas. At the fame time fulphur is depofited.

Another very ftriking experiment on the formation of ammonia, which is eafily made and feldom fails of fuccefs, is the following. Take fome powder, or filings of tin or zinc, pour on them fome moderately dilute nitrous acid, which will act on them with great vehemence, and the difengagement of copious red fumes. After a fhort time ftir into the mixture fome quicklime or cauftic alkali, and a very ftrong pungent fmell of ammonia will be produced. In this cafe the ammonia is formed by the decompofition of the nitrous acid and the water, this ammonia inftantly unites with a portion of the acid, forming nitrated ammonia, and the lime again decompofes this ammoniacal falt by fimple affinity, and by difplacing the alkali from its union with the acid, caufes it to affume the gafeous form and to become evident to the fenfes.

Before we quit the fubject of the compofition of ammonia, we fhall make a few obfervations on the decompofition of nitrous gas and nitric acid in the experiments above related, whereby the volatile alkali is produced. In the fimpler methods of forming ammonia, fuch as in Dr. Auftin's experiments, the union of the nafcent hydrogen with azotic gas, the affinities which operate in forming the alkali, may be fuppofed to be tolerably fimple. But when the nitric acid, or nitrous gas are ufed, the affinities appear to be extremely complex, and perhaps hardly made out with much certainty. It fhould be noted, however, that, along with the production of ammonia, there appears conftantly a proportionate quantity of that fingular gas difcovered by Dr. Prieftley, and called by him dephlogifticated nitrous air; and of late denominated *nitrous oxyd* by Mr. Davy, to whofe highly ingenious "Refearches" we are indebted for much important addition to this curious and difficult part of chemiftry. It is a ftriking property of the nitrous oxyd to fupport combuftion in a very eminent manner, and very fimilar to oxygen gas, although it contains a lefs proportion of oxygen, and more azot than *nitrous gas,*

which is unfit for combuſtion. This reſemblance to oxygen gas in the nitrous oxyd has miſled ſome chemiſts in the nature of the air left after the formation of ammonia from nitrous gas and naſcent hydrogen, who have ſuppoſed a production of oxygen, and have been obliged to account for it accordingly. To explain the changes that take place with moiſtened iron filings, confined in an atmoſphere of nitrous gas, we muſt obſerve, that the new compounds, which we know are formed out of theſe materials, are ammonia, conſiſting of azot and hydrogen, and nitrous oxyd, compoſed of much azot and little oxygen. The iron likewiſe is ruſted or oxygenated. The ſource of the hydrogen in the new products may be ſuppoſed to be ſome of the water decompoſed, from which the metal, in ruſting, has abſtracted its other conſtituent part, the oxygen. The only ſource of the azot (allowed by the antiphlogiſtic theory) is the nitrous gas, which is compoſed merely of this principle, and of oxygen. But if merely a portion of the azot of the nitrous gas was abſtracted from it, the remainder, by loſing azot, would be a ſubſtance containing (proportionally) *more* oxygen than nitrous gas; whereas, the nitrous oxyd, which is this remainder, contains leſs. There muſt, therefore, be an additional method of getting rid of this exceſs of oxygen, in order to produce a ſatisfactory explanation; and the only ſubſtance that offers is the hydrogen of the water decompoſed by the metal, which may be ſuppoſed to unite with enough of the oxygen of the nitrous gas to reduce it to the ſtate of nitrous oxyd. Thus then, according to this hypotheſis, the metal decompoſes the water, the hydrogen ſet at liberty by this decompoſition unites with a ſmall part of the azot of the nitrous gas to form ammonia, and with a greater part of its oxygen, to form water, and the reſidue of the nitrous gas is in that proportion and mixture which conſtitutes nitrous oxyd.

We ſhall not purſue this ſubject farther at preſent, as it will apply to all the caſes of the production of ammonia by nitrous acid, and it may, perhaps, be thought too hypothetical to be further inſiſted on, though there are many ſimilar examples to be met with, of very extenſive and complicated affinities being ſet in motion by a ſingle diſturbance of the quieſcent attractions of the conſtituent parts of any of the ſubſtances contained in the mixture.

Having now enumerated ſome of the leading facts by which the compoſition of the volatile alkali has been eſtabliſhed, we ſhall proceed to mention ſome of the mixtures of ammonia with various chemical agents. It may be obſerved that though the uncombined volatile alkali is in the form of gas when pure, all its combinations are either ſolid or liquid, and hence every ſubſtance added to the ammoniacal gas cauſes an abſorption of it where any chemical action takes place. However, the tendency to the aëriform ſtate is ſo far retained by ammonia in all its combinations as to render them volatile, and to weaken its adheſion for them, whenever the temperature is raiſed to a certain degree. The force of affinity which ammonia exerciſes is therefore remarkably weakened by heat, where the ſubſtance to which it is united is naturally fixed in the fire, and many of the ammoniacal compounds at a high temperature are totally decompoſed, and entirely new products reſult from the operation.

No union takes place by any ſimple mixture of ammonia with oxygen, hydrogen, or azotic gaſſes. Under particular circumſtances, and by the agency of complicated affinities, theſe ſubſtances may however be mutually decompoſed, and new compounds produced. Thus, ammoniacal gas paſſed over heated oxyd of mangancſe forms Nitrous Acid, as diſcovered by the ingenious experiments of Dr. Milner.

Ammonia unites with all the acids with very great eaſe and rapidity, forming with them very eaſily ſoluble ſalts. Theſe will be particularly mentioned under the reſpective acids, but ſome of their properties may here be mentioned. The union of alkaline air with the acid gaſſes, as diſcovered by Dr. Prieſtley, forms ſome of the moſt ſtriking and beautiful experiments which chemiſtry furniſhes. If ammoniacal gas is paſſed up into a jar containing carbonic acid there is a thick white fume immediately produced, the two gaſſes by uniting loſe their gaſeous form, ſo that there is a complete vacuum ſuddenly made in the jar, cauſing the mercury over which it is confined to riſe and fill it entirely, a ſenſible quantity of heat is given out, and a number of minute cryſtals of carbonated ammonia lining the inſide of the jar, is the product of the mixture.

With the muriatic acid gas the appearances are exactly ſimilar, only the white fume is ſtill more denſe and copious, the heat greater, and the union more rapid. Cryſtalline feathers of Muriated ammonia are the reſult, and this furniſhes one of the moſt ſtriking inſtances of alteration in form, and in ſenſible properties, which two bodies may undergo by chemical affinity; for each of the ingredients when ſeparate are in the ſtate of an inviſible gas with a highly pungent ſmell, and, when united, a ſcentleſs ſolid ſalt is the product. In making this beautiful experiment both the gaſſes ſhould be confined over mercury; and, on account of the much ſuperior ſpecific gravity of the acid gas over the alkaline, if the former is thrown into a jar of the latter, the white cloud will form ſlowly, beginning from the point of contact of the gaſſes; but if the alkali be added to the acid gas, it riſes through it immediately, and the combination takes place with great rapidity.

The nitrous acid unites with ammonia with great eaſe, and with the production of white fumes when the two ſubſtances are gaſeous. The reſulting ſalt Nitrat of ammonia poſſeſſes very intereſting properties, which will be mentioned under that article.

It may be of uſe to know that the preſence of ammoniacal gas, where it cannot conveniently be detected by the ſmell, will be readily ſhewn by holding a piece of glaſs rod or any other ſubſtance wetted with nitrous or muriatic acid, over the part where ammonia is ſuſpected, when thick white fumes will be ſeen to form around the acid.

Phoſphorus will not unite with ammonia at a low temperature. In a red heat the alkali is decompoſed, and phoſphorated hydrogen, and azotic gas are produced.

With ſulphur, ammonia unites with ſome difficulty, forming the Sulphuret of ammonia, or *Boyle's fuming liquor*.

Charcoal and the volatile alkali do not unite in a moderate heat, but at high temperatures the alkali is decompoſed, and, by particular management, that ſingular ſubſtance, the Prussic acid, may be formed.

The affinity of ammonia for the different acids is much weaker than that of the other alkalies, and ſeveral of the earths. In ſeveral ſolutions of earths or metals in acids, where the affinity of ammonia for the acid is only in a ſmall degree greater than of the earth or metal, only a part of the ſubſtance diſſolved is precipitated by the addition of this alkali, and the ſolution retains the remainder, united with the ammonia, forming together an ammoniacal triple ſalt. Thus if to a ſolution of magneſia ammonia is added, part only of the earth is precipitated, and the remaining ſolution is an ammoniaco-magneſian ſalt. Alſo the affinities of ammonia are much weakened by heat, owing to the great tendency to volatilization which the alkali poſſeſſes.

Ammonia has a very ſtriking property of reducing to the metallic ſtate (either entirely or partially) the oxyds of the ſeveral metals. This is performed, as we have already men-

tioned in the inſtance of fulminating gold, by a decompoſition of the alkali, its hydrogen uniting with the oxygen of the metallic oxyd to form water, and its azot appearing uncombined in the form of gas. Thus, as M. Fourcroy has obſerved, (*An. Chym. tom.* 2 & 6.) if the black oxyd of manganeſe is moiſtened with liquid ammonia, and gentle heat be applied, the oxyd paſſes to the ſtate of the white oxyd, (which is nearer the metallic ſtate) and an effervefcence with diſengagement of azotic gas takes place. The red oxyd of mercury, treated in a ſimilar manner, gives the ſame reſults, and the metal is left in the ſtate of a black powder, which ſimple expoſure to light and air will convert to globules of running mercury. This affords a ready way of cleaning the ſurface of mercury that has been tarniſhed and oxydated by acid vapours.

Some of the moſt difficultly reducible metals, ſuch as manganeſe or tungſten, are on this account beſt prepared for reduction by being previouſly united with ammonia.

The volatile alkali may be made to unite with oils, ſo as to form ammoniacal SOAPS; but this combination is leſs perfect than the fixed alkaline ſoaps, on account of the impoſſibility of applying heat to promote union without driving off much of the alkali in the form of gas. The volatile oils are equally ſoluble in ammonia with the fixed, an example of which is that union of oil of amber with ammonia, which forms EAU DE LUCE.

A great variety of vegetable and animal ſubſtances are diſſolved or decompoſed by this alkali, which renders it of the higheſt importance in the ANALYSIS of animal and vegetable matters.

The uſes of the volatile alkali are numerous and important. To the chemiſt, as a re-agent of very extenſive utility, it is an indiſpenſable requiſite, as there is hardly a ſingle analyſis of mineral, vegetable, or animal matter performed (where at all complicated) in which ammonia is not largely employed.

In medicine this alkali is highly valuable, on account of its ſtrong and diffuſibly ſtimulant properties. When taken internally, its firſt effect is generally upon the throat and fauces, owing to its partial volatilization by the heat of the mouth. Every one is familiar with its uſe in relieving faintings and ſickneſs when ſnuffed up the noſtrils, though from the great acrimony of the cauſtic ammonia, the milder form of the carbonated ammonia, or *ſal volatile* is generally preferred. The ſtrong and ſudden ſtimulus which it gives to the ſyſtem, when applied to the noſtrils, renders it alſo one of the moſt powerful applications in many of the more ſerious ſuſpenſions of the vital powers. The pure liquid ammonia is much too acrid to be uſed by itſelf, even as an external application, but when mixed with oil it forms a very uſeful liniment for ſtrains, indolent ſwellings, and any caſe in which a powerful ſtimulant is required. Simple agitation with oil will unite the two liquors into an uniform milky ſaponaceous liquid, in which the ſenſible properties of the alkali are only blunted and not neutralized. A peculiar uſe of the liquid ammonia largely diluted with water, and taken internally, is in checking the ſudden and dreadful effects produced by the bite of venomous ſerpents.

Prieſtley on Air.—*Journal de Phyſique for* 1785, 6, *and* 7.—*Philoſ. Tranſact. for* 1788.—*Anal. de Chimie, tom.* ii. & vi.—*Davy's Reſearches,* &c. &c.

AMMONIA, in *Mythology*, an appellation of Juno, to whom the Eleans ſacrificed, alluding, perhaps, to Jupiter Ammon.

Anchor

ANCHOR, Anchora, from the Latin *ancora*, or *anchora*, of the Greek αγκυρα, which comes from αγκυλος, *incurvus*, *crooked*, a large, ſtrong, and heavy piece of iron, compoſed of a long ſhank, having at one end a ring to which the cable is faſtened, and at the other two arms or flukes, with barbs or edges on each ſide, and uſed for fixing and retaining a veſſel in a harbour, road, or river.

The anchor is an inſtrument of very ancient uſe. Pliny (lib. viii. c. ult.) aſcribes the invention of it to the Tuſcans; and Pauſanias (Attic, lib. i. c. 4. p. 12.) refers it to Midas, the ſon of Gordius, who built the city Ancyra. The moſt ancient anchors were of ſtone, and ſometimes of wood, to which a quantity of lead was attached; in ſome places they uſed baſkets full of ſtones, and ſacks filled with ſand. Theſe were ſuſpended by cords, and their weight regulated the courſe of the ſhip. Afterwards anchors were conſtructed of iron, and furniſhed with teeth or flukes, which faſtening to the bottom of the ſea, kept the ſhip immoveable; hence οδοντες, teeth, are uſed for anchors. The firſt anchors had only a tooth or fluke, on one ſide; and on this account they were denominated ετεροστομοι; the contrivance was completed, according to Pliny, (*ubi ſupra*,) by Eupalamus, who made them fluked both ways, or according to Strabo (lib. vii. ex Ephor, tom. p. 464.) the ſecond tooth or fluke was added by Anacharſis, the Scythian. The anchors with two teeth were called αμφιβολοι, or αμφιστομοι. Every ſhip had ſeveral anchors, the largeſt of which was called ιερα, ſacred, and was never uſed but in extreme danger; whence the phraſe "ſacram anchoram ſolvere," is proverbially applied to ſuch as are reduced to their laſt refuge.

All anchors have now two arms; not but they might ſtill be uſed with only one arm, which ſtructure would have this advantage, that they would be lighter, and yet in fine weather would hold equally firm with the double kind. The reaſon of having two arms is, that the anchor may always take, in order to which it is neceſſary that it be very heavy; beſides, that anchors with a ſingle arm would require more preparation for ſervice.

Travellers tell us of people who make uſe of wooden anchors in their navigation. The inhabitants of the iſland of Ceylon, in lieu of anchors, uſe large round ſtones, and in

in other places, their anchors are a kind of wooden machines, loaded with ſtones. Sometimes bags of ſand have been made uſe of, but theſe chiefly obtained in rocky places, where anchors would not take hold. In England, France, and Holland, anchors are made of forged iron; but in Spain, they are ſometimes made of copper, and likewiſe in ſeveral parts of the South ſea.

The anchors now made are ſo contrived as to ſink into the ground as ſoon as they reach it, and to hold a great ſtrain before they can be looſened or diſlodged from their ſtation. The parts of which an anchor is compoſed are the ring, into which the cable is faſtened, the beam, or ſhank, which is the longeſt part of the anchor, the two arms, at the end of which are the two flooks or flukes, by ſome called the palms, which with their barbs faſten into the ground, and the ſtock, which is a long piece of wood, faſtened acroſs the beam, near the ring, and ſerving to guide the flukes in a direction perpendicular to the ſurface of the ground; ſo that one of them ſinks into it by its own weight, as ſoon as it falls, and is ſtill preſerved ſteadily in that poſition by the ſtock, which, together with the ſhank, lies flat on the bottom. In this ſituation it muſt neceſſarily ſuſtain a great effort before it can be dragged through the earth horizontally. This, indeed, can only be effected by the wind or tide, or by both of them; the effect of which is ſometimes increaſed by the turbulency of the ſea, and acts upon the ſhip ſo as to ſtretch the cable to its utmoſt tenſion, and may thus diſlodge the anchor from its bed, eſpecially if the ground be ſoft, and oozy, or rocky. When the anchor is thus diſplaced, it is ſaid, in the ſea-phraſe, "to come home."

The ſeveral parts of the anchor, above enumerated, bear the following proportions. The length of the arm, from the inſide of the throat to the bill, is the diſtance marked on the ſhank for the trend, taken from the inſide of the throat; and three times that is the length of the ſhank from the tip of the crown; and the ſhank, from the tip of the crown to the centre of the ring, is the length of the iron ſtock; when made, the two arms, from the inſide of the throat to the extremity of the bill, ſhould form an arc of a circle, containing 120 degrees. See *Plate* XI. *Ships*.

Of anchors there are the ſheet, beſt bower, ſmall bower, and ſpare anchor. Theſe do not vary in form or weight from each other, in the navy. Stream and kedge anchors are ſmaller, and grapnels are only for boats. Ships of 110, 100, 98, and 90 guns, have ſeven anchors; from 80 to 20 guns incluſive, ſix anchors; ſhips of 300 tons, and ſloops have five; and brigs and cutters three anchors.

Anchors, *method of making*. The goodneſs of the anchor is a point of great importance; the ſafety and conſervation of the veſſel depending principally upon it. The ſhank, arms, and flukes, are firſt forged ſeparately; then the hole is made at one end of the ſhank for the ring, which being alſo previouſly forged, is put into the hole of the ſhank, and the two ends ſhut together. After which the arms are ſhut to the ſhank, one after the other, and the anchor is finiſhed.

The ſhank is made of many long bars of the beſt tough iron, well wrought together; and great care ſhould be taken, that the iron be neither too ſoft nor too brittle; the latter rendering it liable to break, and the former to ſtraiten. The number of bars ſufficient to make the ſhank of the intended ſize, muſt be regulated by experience. Several parts of the anchor are governed by the ſize of the trend, which is marked on the ſhank at the ſame diſtance from the inſide of the throat as the arm meaſures from the inſide of the throat to the extremity of the bill. The ſhank is rounded to the ſquare of the upper part, and is there called the ſmall round, being the ſmalleſt part. The two ſides in the direction of the arms are flatted ſurfaces, about an inch leſs than the trend, in large anchors, and ſomething leſs in ſmaller ones. The ſquared part is of the ſame ſize as at the trend each way, and hanches into the ſmall round, one-ſixth of the length of the ſhank. The hole, or eye, for the ring, is punched through the ſquare part, or the flatted ſide, once and a half the thickneſs of the ring, from the upper extremity of the ſhank, which has its corners flatted or diamonded, on the ſame ſides, nearly in the middle. Between the hole for the ring and lower part of the ſquare are too ſmall prominences, raiſed acroſs from the ſolid, called nuts, for ſecuring the ſtock in its place. At the lower part of the ſhank is left a ſcarf, or flatted ſurface, with a ſhoulder on each ſide, for ſhutting on the arms.

In making every part of an anchor the niceſt attention ſhould be obſerved, as to its being ſmooth, fair, and even; and that the edges and angles are preſerved ſtraight in their direction, as well-made anchors ſhould poſſeſs beauty as well as ſtrength. The ring, being previouſly forged, is put through the fore-mentioned hole in the ſhank, and the two ends are well ſhut together. The arms are made of ſhorter bars than the ſhank, but as good in quality, and as well put together; they are rounded and flatted on the different ſides, to reſemble the ſhank, and are of the ſame ſize as the ſhank, at the throat and ſmall round. The rounding part is continued to the palm, which is nearly in the middle of the arm; from thence it is made with a ſquare tapering to the bill on the flatted ſide; and, on the inner rounded ſide, is made a ſquare ſeat for ſhutting on the palm, that the palm, when ſhut on, ſhould project its thickneſs at the baſe or inner part, the outer part making a ſtraight ſurface with the peek or bill. The back or outer ſide of the arm is made ſtraight from the rounded part, or hanch, to the ſnape, and there kept to half the ſubſtance of the inner part. The ſnape reſembles the bill of a duck, and is one-third the breadth of the palm in length. The thickneſs of the ring is to be half the diameter of the ſmall round. The diameter of the ring, including the thickneſs, reaches from the hole in the upper part of the ſhank to the hanch of the ſmall round. The inner part of the arm is moſtly made ſtraight, from the bill to the throat; and it is thought ſtronger for having a ſmall angle in its length, inclining to the ſhank. Shanks taper in their length, one and one-half inch in ſmall anchors to three inches in large, keeping their proper ſize at the trend; and three-fourths of an inch to two inches in the flatted way. The arm in its length inclines to the ſhank, and forms a ſmall angle, the touch or point thereof being in the middle. The throat-end of the arm is ſcarfed, or flatted, to anſwer the ſcarf in the ſhank, to which the two arms are united (after the palms are ſhut on) in the firmeſt manner poſſible; and it is elevated above the horizontal plane, or inclined to the ſhank, that each arm may ſpread at the peek or bill. The length of the arm, from the inſide of the throat to the extremity of its bill, is then taken, and that length from the inſide of the throat is ſet upon the ſhank, and called the trend; from the trend to the bill is formed an angle of about 60 degrees. The palms, or flukes, are two thick plates of iron, made of various pieces, well wrought together, in the form of an iſoſceles triangle; one and one-half inch to one and one-fourth inch longer than the breadth of the baſe, and curve about as much in their ſides. The baſe or lower part, is to be ſtraight; the inner flat ſurface curves a little in the breadth, but is ſtraight

lengthways; the palms, being finished thus far, are, lastly shut firmly into the inner side of the arm, in the seat befor mentioned, the base inclining inwards.

The stock is composed of two long beams of oak, strongly bolted and tree-nailed together, and secured with four strong iron hoops, two on each side of the middle, and one near each end. It is fixed on the upper end of the shank, transversely with the flukes or palms; and the nuts are let into the middle of the stock. The length of the stock is the length of the shank and half the diameter of the ring; the depth and thickness in the middle are as many inches as the stock is feet in length. The ends are to be kept square, half the depth or thickness in the middle. The upper side next the ring is always kept straight, as is the lower side half the depth on each side the middle; and thence it tapers to each end in the above proportion. It is necessary to leave an opening in the middle of one and one-half inch, between the two pieces, that the hoops may be driven nearer the middle, in case the stock should shrink. The making of anchors is a very laborious business, and has been much facilitated by the invention of two machines, called the HERCULES and the MONKEY.

Proof is made of anchors, by raising them to a great height, and then letting them fall again on a kind of iron block placed across for the purpose. To try whether the flukes will turn to the bottom, and take hold of the ground, they place the anchor on an even surface, with the end of one of the flukes, and one of the ends of the stock resting on the surface; in case the anchor turns, and the point of the fluke rises upwards, the anchor is good.

For the proportions of anchors according to Manwaring, the shank is to be thrice the length of one of the flukes, and half the length of the beam. According to Aubin, the length of the anchor is to be four-tenths of the greatest breadth of the ship; so that the shank, *e. gr.* of an anchor in a vessel thirty feet wide, is to be twelve feet long. When the shank is, for instance, eight feet long, the two arms are to be seven feet long, measuring them according to their curvity. As to the degree of curvity given the arms, there is no rule for it; the workmen are here left to their own discretion.

Aubin, in his Marine Dictionary, gives a table from a Flemish writer, wherein the lengths of the shanks of anchors for vessels of all widths, is computed, as well as the weights of the anchors, from a vessel eight feet wide within, which requires an anchor three and one-half feet long, weighing thirty-three pounds, to a vessel forty-five feet wide, which demands an anchor eighteen feet long, and weighing 5832 pounds. He likewise observes, that the anchor of a large heavy vessel is smaller, in proportion, than that of a lesser and lighter one. The reason he gives is, that though the sea employs an equal force against a small vessel as against a great one, supposing the extent of wood upon which the water acts to be equal in both, yet the little vessel, by reason of its superior lightness, does not make so much resistance as the greater; the defect whereof must be supplied by the weight of the anchor.

From these and other hydrostatic principles, the following table has been formed; wherein is shewn, by means of the ship's breadth within, how many feet the beam or shank ought to be long, giving it $\frac{4}{10}$ or $\frac{2}{5}$ of the ship's breadth within; by which proportion may be regulated the length of the other parts of the anchor. In this table is represented likewise the weight an anchor ought to be for a ship from eight feet broad to 45, increasing by one foot's breadth; supposing that all anchors are similar, or that their weights are as the cubes of the lengths of the shanks.

Breadth of the Vessel. Feet.	Length of the Anchor. Feet.	Weight. Pounds.
8	$3\frac{1}{5}$	33
9	$3\frac{3}{5}$	47
10	4	64
11	$4\frac{2}{5}$	84
12	$4\frac{4}{5}$	110
13	$5\frac{1}{5}$	140
14	$5\frac{3}{5}$	175
15	6	216
16	$6\frac{2}{5}$	262
17	$6\frac{4}{5}$	314
18	$7\frac{1}{5}$	373
19	$7\frac{3}{5}$	439
20	8	512
21	$8\frac{2}{5}$	592
22	$8\frac{4}{5}$	681
23	$9\frac{1}{5}$	778
24	$9\frac{3}{5}$	884
25	10	1000
26	$10\frac{2}{5}$	1124
27	$10\frac{4}{5}$	1259
28	$11\frac{1}{5}$	1405
29	$11\frac{3}{5}$	1562
30	12	1728
31	$12\frac{2}{5}$	1906
32	$12\frac{4}{5}$	2097
33	$13\frac{1}{5}$	2300
34	$13\frac{3}{5}$	2515
35	14	2742
36	$14\frac{2}{5}$	2986
37	$14\frac{4}{5}$	3242
38	$15\frac{1}{5}$	3512
39	$15\frac{3}{5}$	3796
40	16	4096
41	$16\frac{2}{5}$	4426
42	$16\frac{4}{5}$	4742
43	$17\frac{1}{5}$	5088
44	$17\frac{3}{5}$	5451
45	18	5832

M. Bouguer directs to take the length of the shank in inches, and to divide the cube of it by 1160 for the weight. The reason is obvious; because the quotient of the cube of 201 inches, which is the length of an anchor weighing 7000lb. divided by the weight is 1160, and therefore by the rule of three, this will be a common divisor for the cube of any length, and a single operation will suffice. The same author, in his Traite de Navire, gives the following dimensions of the several parts of an anchor. The two arms generally form the arch of a circle, whose centre is three eighths of the shank from the vertex, or point where it is fixed, to the shank; and each arm is equal to the same length or the radius; so that the two arms together make an arch of 120 degrees: the flukes are half the length of the arms, and their breadths two-fifths of the said length. With respect to the thickness, the circumference at the throat, or vertex of the shank, is generally made about the fifth part of its length, and the small end two thirds of the throat, the small end of the arms of the flukes, three fourths of the circumference of the shank at the throat. These dimensions should be bigger, when the iron is of a bad quality, especially if cast iron is used instead of forged iron.

THE MOST APPROVED DIMENSIONS AND WEIGHT OF ANCHORS.

Weight.	Length of the Shank.		Length of the Arms.		Breadth of the Palms.		Thickness of the Palms.		Size of the Trend.		Size of the small Round.		Outer Diamet. of the Ring.		Thickness of the Ring.	
Ct.	Ft	In.	Ft	In.	Ft	In.	Ft	In.	Ft	In.	Ft	In.	Ft	In.	Ft	In.
1	5	8	1	10	0	9	0	0¾	0	2½	0	2	0	9	0	1
2	6	6	2	2	0	11	0	0¾	0	2¾	0	2¼	0	11	0	1⅛
3	7	0	2	4	1	0	0	0⅞	0	3	0	2½	1	0	0	1¼
4	7	6	2	6	1	1	0	0⅞	0	3¼	0	2¾	1	1	0	1⅜
5	8	0	2	8	1	2	0	1	0	3½	0	3	1	2	0	1½
6	8	6	2	10	1	3	0	1	0	3¾	0	3¼	1	3	0	1⅝
7	9	0	3	0	1	4	0	1	0	4	0	3½	1	4	0	1¾
8	9	6	3	2	1	5	0	1⅛	0	4¼	0	3¾	1	5	0	1⅞
9	10	0	3	4	1	6	0	1⅛	0	4⅜	0	3⅞	1	6	0	1 15/16
10	10	4	3	5	1	7	0	1⅛	0	4½	0	4	1	7	0	2
11	10	8	3	7	1	8	0	1¼	0	4⅝	0	4⅛	1	8	0	2 1/16
12	11	0	3	8	1	8¼	0	1¼	0	4⅝	0	4⅛	1	8¼	0	2 1/16
13	11	4	3	10	1	8½	0	1¼	0	4¾	0	4¼	1	8½	0	2⅛
14	11	8	3	11	1	8¾	0	1¼	0	4⅞	0	4⅜	1	8¾	0	2 3/16
15	12	0	4	0	1	9	0	1⅜	0	5	0	4½	1	9	0	2¼
16	12	3	4	1	1	9⅛	0	1⅜	0	5⅛	0	4⅝	1	9⅛	0	2 5/16
17	12	6	4	2	1	9¼	0	1⅜	0	5¼	0	4¾	1	9¼	0	2⅜
18	12	8	4	3	1	9½	0	1⅜	0	5⅜	0	4⅞	1	9½	0	2 7/16
19	12	10	4	4	1	9⅝	0	1½	0	5½	0	5	1	9⅝	0	2½
20	13	0	4	4½	1	9¾	0	1½	0	5⅝	0	5⅛	1	9¾	0	2 9/16
21	13	2	4	5	1	9¾	0	1½	0	5⅞	0	5⅛	1	9¾	0	2 9/16
22	13	4	4	5⅜	1	10	0	1½	0	6⅛	0	5⅜	1	10	0	2 11/16
23	13	6	4	6	1	10¼	0	1½	0	6¼	0	5½	1	10¼	0	2¾
24	13	8	4	6½	1	10½	0	1½	0	6⅜	0	5⅝	1	10½	0	2 13/16
25	13	10	4	7	1	11	0	1⅝	0	6½	0	5¾	1	11	0	2⅞
26	14	0	4	8	1	11½	0	1⅝	0	6⅝	0	5⅞	1	11½	0	2 15/16
27	14	2	4	8½	1	11¾	0	1⅝	0	6⅝	0	5⅞	1	11¾	0	2 15/16
28	14	4	4	9¼	1	11¾	0	1⅝	0	6⅝	0	5⅞	1	11¾	0	2 15/16
29	14	6	4	10	2	0	0	1¾	0	6⅝	0	5⅞	2	0	0	2 15/16
30	14	7½	4	10½	2	0½	0	1¾	0	6¾	0	6	2	0½	0	3
31	14	9	4	11	2	1	0	1⅞	0	6¾	0	6	2	1	0	3
32	14	10	4	11½	2	1½	0	1⅞	0	6⅞	0	6⅛	2	1½	0	3 1/16
33	15	0	5	0	2	1¾	0	1⅞	0	7	0	6¼	2	1¾	0	3¼
34	15	1	5	0¼	2	2	0	2	0	7⅛	0	6¼	2	2	0	3¼
35	15	2	5	0⅜	2	2½	0	2	0	7⅜	0	6⅜	2	2½	0	3 5/16
36	15	4	5	1¼	2	2¾	0	2	0	7½	0	6½	2	2½	0	3⅜
37	15	6	5	2	2	3	0	2	0	7½	0	6½	2	3	0	3⅜
38	15	7	5	2¼	2	3½	0	2⅛	0	7⅝	0	6⅝	2	3½	0	3 7/16
39	15	9	5	3	2	3¾	0	2⅛	0	7⅝	0	6⅞	2	3¾	0	3 7/16
40	15	10	5	3½	2	4	0	2¼	0	7¾	0	7	2	4	0	3½
41	16	0	5	4	2	4¼	0	2½	0	7¾	0	7	2	4½	0	3½

Weight.	Length of the Shank.		Length of the Arms.		Breadth of the Palms.		Thickness of the Palms.		Size of the Trend.		Size of the small Round.		Outer Diamet. of the Ring.		Thickness of the Ring.	
Ct.	Ft	In.	Ft	In.	Ft	In.	Ft	In.	Ft	In.	Ft	In.	Ft	In.	Ft	In.
42	16	1	5	4¼	2	4½	0	2½	0	7¾	0	7	2	4½	0	3½
43	16	2	5	4½	2	5	0	2½	0	7⅞	0	7⅛	2	5	0	3 9/16
44	16	3	5	5	2	5¼	0	2½	0	7⅞	0	7⅛	2	5¼	0	3 9/16
45	16	4	5	5¼	2	5½	0	2½	0	8	0	7¼	2	5½	0	3⅝
46	16	5	5	5½	2	5¾	0	2½	0	8	0	7¼	2	5¾	0	3⅝
47	16	6	5	6	2	6	0	2½	0	8⅛	0	7⅜	2	6	0	3 11/16
48	16	7	5	6¼	2	6¼	0	2½	0	8⅛	0	7⅜	2	6¼	0	3 11/16
49	16	8	5	6½	2	6½	0	2⅝	0	8⅛	0	7⅜	2	6½	0	3 11/16
50	16	9	5	6¾	2	7	0	2⅝	0	8¼	0	7½	2	7	0	3¾
51	16	10	5	7	2	7½	0	2⅝	0	8¼	0	7½	2	7½	0	3¾
52	16	11	5	7½	2	8	0	2⅝	0	8¼	0	7½	2	8	0	3¾
53	17	0	5	7¾	2	8¼	0	2⅝	0	8⅜	0	7⅝	2	8¼	0	3 13/16
54	17	1	5	8¼	2	8⅝	0	2⅝	0	8⅜	0	7⅝	2	8⅝	0	3 13/16
55	17	2	5	8½	2	9	0	2¾	0	8½	0	7¾	2	9	0	3⅞
56	17	3	5	9	2	9¼	0	2¾	0	8½	0	7¾	2	9¼	0	3⅞
57	17	4	5	9½	2	9½	0	2¾	0	8½	0	7¾	2	9½	0	3⅞
58	17	5	5	9¾	2	10	0	2¾	0	8¾	0	7⅞	2	10	0	3 15/16
59	17	6	5	10	2	10¼	0	2¾	0	8⅞	0	7⅞	2	10¼	0	3 15/16
60	17	7	5	10¼	2	10½	0	2⅞	0	8¾	0	7⅞	2	10½	0	3 15/16
61	17	8	5	10½	2	11	0	3	0	8¾	0	8	2	11	0	4
62	17	9	5	11	2	11½	0	3	0	8¾	0	8	2	11½	0	4
63	17	10	5	11¼	2	11¾	0	3	0	8⅞	0	8	2	11¾	0	4
64	17	11	5	11¾	3	0	0	3	0	8⅞	0	8	3	0	0	4
65	18	0	6	0	3	0	0	3⅛	0	9	0	8	3	0	0	4
66	18	1	6	0¼	3	0	0	3⅛	0	9	0	8	3	0	0	4
67	18	2	6	0½	3	1	0	3⅛	0	9	0	8	3	1	0	4
68	18	3	6	1	3	1	0	3⅛	0	9⅛	0	8	3	1	0	4
69	18	3½	6	1½	3	1	0	3⅛	0	9⅛	0	8	3	1	0	4
70	18	4	6	1¾	3	1	0	3¼	0	9¼	0	8⅛	3	1	0	4 1/16
71	18	5	6	1¾	3	1½	0	3¼	0	9¼	0	8⅛	3	1½	0	4 1/16
72	18	6	6	2	3	1½	0	3¼	0	9⅜	0	8¼	3	1½	0	4 1/16
73	18	8	6	2½	3	1½	0	3¼	0	9⅜	0	8¼	3	1½	0	4 1/16
74	18	9½	6	3	3	1½	0	3⅜	0	9⅜	0	8¼	3	1½	0	4 1/16
75	18	11	6	3½	3	1¾	0	3⅜	0	9⅜	0	8¼	3	1¾	0	4 1/16
76	19	0⅜	6	4⅛	3	2	0	3⅜	0	9⅜	0	8¼	3	2	0	4 1/16
77	19	1¾	6	4⅝	3	2	0	3½	0	9½	0	8 1/16	3	2	0	4⅛
78	19	3⅛	6	5	3	2	0	3½	0	9½	0	8 3/16	3	2	0	4⅛
79	19	4½	6	5½	3	2	0	3½	0	9½	0	8¼	3	2	0	4⅛
80	19	6	6	6	3	2	0	3½	0	9½	0	8¼	3	2	0	4⅛
81	19	8	6	6⅝	3	2½	0	3⅝	0	10	0	8¼	3	2½	0	4⅛

The Number of Anchors allowed each Ship in the Royal Navy, with their Weight and Value.

S. stands for Stream, K. for Kedge.

No	110 & 100 Guns.		Value		No.	98 and 90 Guns.		Value.		No	80 and 74 Guns.		Value.		No.	Smaller 74 Guns.		Value.		No.	64 Guns.		Value.	
	Cwt.	Qr	l.	s.		Cwt.	Qr	l.	s.		Cwt.	Q.	l.	s.		Cwt.	Qr	l.	s.		Cwt.	Qr	l.	s.
5	81	0	1215	0	4	73	0	1003	15	4	71	0	781	0	4	67	0	670	0	4	57	0	502	2
S. 1	21	0	32	11	S. 1	18	0	27	0	S. 1	17	2	26	0	S. 1	16	0	24	0	S. 1	15	0	22	10
K. 1	10	2	15	15	K. 1	9	0	13	10	K. 1	8	2	12	10	K. 1	8	0	12	0	K. 1	7	2	11	0
No.	60 Guns.		Value		No.	50 Guns.		Value.		No.	44 and 38 Guns		Value		No.	36 Guns.		Value.		No.	32 Guns.		Value.	
4	53	0	437	17	4	49	0	382	4	4	40	0	272	0	4	39	0	240	16	4	33	0	210	4
S. 1	12	0	18	0	S. 1	11	0	16	10	S. 1	10	0	15	0	S. 1	9	0	13	10	S. 1	8	1	12	5
K. 1	6	0	9	0	K. 1	5	2	8	0	K. 1	5	0	7	10	K. 1	4	2	6	10	K. 1	4	0	6	0
No.	28 Guns.		Value.		No.	24 and 20 Guns.		Value.		No.	14 Guns 300 Tons.		Value.		No.	Sloops, 200 Tons		Value.		No.	Brigs, 200 Tons		Value.	
4	31	0	198	8	4	29 25	2 0	180 155	11 6 0 0	3	20	0	93	0	3	15	0	67	10	3	12	0	54	0
S. 1	8	0	12	0	S. 1	7	2	11	0	S. 1	7	0	10	10	S. 1	6	0	9	0		Cutter			
K. 1	4	0	6	0	K. 1	3	2	5	0	K. 1	3	2	5	0	K. 1	3	0	4	10	3	10	0	45	0

See Murray's Treatise on Ship-building, &c. Elements and Practice of Rigging and Seamanship, 4to. 1794, p. 77—82.

The distinctions of anchors are taken from their use, and the proportions they bear in the ship, where they are employed; for that which in one ship would be called but a *kedger*, or *kedge*-ANCHOR, in a lesser would be a *sheet*-ANCHOR.

ANCHOR, *kedge*, is the smallest, which, by reason of its lightness, is first to stop the ship in *kedging* a river.

This is what the Dutch sailors call *werp*-ANCHOR, the French *ancre a touer*. It ought to weigh 450 pounds.

The *grapnel* is an anchor for a small ship or boat. See KEDGE and GRAPNEL.

ANCHOR, *stream*, is a small anchor fastened to a stream-cable, wherewith to ride in rivers, and gentle streams, and to stop a tide withal in fair weather.

ANCHOR *sheat*, or *sheet*, is the biggest and strongest, being that which the seamen call their last hope; never to be used but in great extremity.

This is what the Romans call *anchora sacra*; the Dutch *plegt-anker*, and *stop-anker*; the French *maitresse-ancre*, or *grand ancre*.

The other anchors are called by the name of the first, second, and third anchor; by any of which the ship may ride in any seasonable weather, sea-gate, or tide.—These are something bigger one than another, and usually when they sail in any streights, or are near a port, they carry two of these at their bow; in which respect they are also called by the name of first and second bowers.

ANCHOR, *second*, called by the Dutch *borg-anker*, or *dagelyks-anker*, is that ordinarily made use of.

ANCHOR, *cross*, called by the Dutch *tuy-anker*, or *vertuy-anker*, and by the French *ancre d'affourche*, is a middling anchor thrown across or opposite to another.—This ought to weigh 1500 pounds, or nearly as much as the second anchor.

ANCHOR, *floating*, is a simple machine, which is made to dive beneath the swell of the sea, and retain the vessel where there may be no other anchorage. It consists of two flat bars of iron, each in length half the breadth of the midship beam of the vessel for which it is used, and rivetted together in the middle by an iron saucer-headed bolt, clenched at its point, that they may be swung parallel to each other for easy stowage. At each end of the bars is a hole for a rope, or swifter to pass through, which must be hove tight to extend the bars at right angles. To this swifter is marled a double or four-fold canvas cloth, so as to be on that side of the iron bars nearest the vessel when used. In each bar are two holes, at equal distances from the centre, and to these holes the ends of two pieces of rope are fastened; the ropes are seized together in the middle so as to form a crow-foot, having an eye in the centre, which is well sewed with spun-yarn, and to this is bent, when the anchor is used, a cable or hawser, by which it is made to sink and incline in the water. See *Plate* XI. *Ships*. In the end of one of the bars is fitted an iron ring to which a buoy is made fast, by a rope about 12 fathoms long, to prevent the anchor from sinking to the bottom. When it is thrown over-board, the cable and a rope made fast to the head of a buoy, are carried away sufficiently to ride the vessel. To get it on board, haul upon the buoy-top, which will bring it to the water's surface so as to be easily drawn to the vessel. Have the mizen stay-sail ready to hoist, so as to keep the vessel to the wind, till the anchor is hauled on board.

A *floating* or *swimming anchor* will serve to prevent a ship, in a storm, from driving to leeward in deep water. Dr. Franklin suggests that an anchor, effectual for this purpose, ought to have the following properties. It should have a surface so large as being at the end of a hauser in the water, and placed perpendicularly, should hold so much of it, as to bring the ship's head to the wind, in which situation the wind has least power to drive her. It should be able by its resistance to prevent the ship's receiving way. It should be capable of being situated below the heave of the sea, but not below the undertow. It should not take up too much room in the ship. It should be easily thrown out, and put into its proper situation. And lastly, it should be easy to take in again, and stow away. Many contrivances have been

ſuggeſted for this purpoſe. One for a large ſhip might have a ſtem of wood 25 feet long and four inches ſquare, with four boards, 18, 16, 14, and 12 feet in length, and one foot wide, with a hole in the middle of each, about four inches ſquare, ſo that it might be occaſionally ſlipt upon the ſtem at right angles with it; and when theſe boards are fixed at the diſtance of four feet from each other, the anchor would have the appearance of the old mathematical inſtrument called the foreſtaff. This thrown into the ſea, and held by a hawſer veered out to ſome length, would bring a veſſel up and prevent her driving, and when taken in it might be ſtowed away by ſeparating the boards from the ſtem. Such a ſwimming anchor would have ſome good effect, but as it lies on the ſurface of the ſea, it is liable to be hove forward by every wave, and then only give ſo much leave for the ſhip to drive. Dr. Franklin has propoſed two machines for this purpoſe, which he conceives, would be more effectual and more manageable. The firſt of theſe is to be formed, and uſed in the water on almoſt the ſame principles, with thoſe of a paper kite in the air; only that as the paper kite riſes in the air, this is to deſcend in the water; and its dimenſions muſt be different for ſhips of different ſizes. The other machine is to be made more in the form of an umbrella. See a particular deſcription of both theſe machines, with figures, in the Tranſactions of the American Philoſophical Society, vol. ii. p. 311—314.

Anemometer & Anemoscope

ANEMOMETER, compounded of ανεμος, *wind*, and μετρον, *measure*, in *Mechanics*, a machine wherewith to measure the force and velocity of the wind. The anemometer is variously contrived. The first of the kind seems to have been invented by Wolfius in 1708, and first published in his "Aerometry" in 1709, and also in the "Acta Eruditorum" of the same year; afterwards in his "Mathematical Dictionary," and also in his Elementa Matheseos," vol. ii p. 319. In the Philosophical Transactions we have one described, in which the wind being supposed to blow directly against a flat side or board, which moves along the graduated limb of a quadrant, the number of degrees it advances shews the comparative force of the wind.

This machine is moved by means of sails, A, B, C, K, (*Plate* IX. *Pneumatics*, *fig.* 69.) like those of a wind mill, which raise a weight L, that, still the higher it goes, receding farther from the centre of motion, by sliding along a hollow arm K M, fitted on to the axis of the sails, becomes heavier and heavier, and presses more and more on the arm, till being a counterpoise to the force of the wind on the sails, it stops the motion thereof. An index then, M N, fitted upon the same axis at right angles with the arm, by its rising or falling, points out the strength of the wind, on a plane divided like a dial-plate into degrees.

It is objected to this machine, however, that it requires a considerable wind to make it work. Leutmannus has contrived another, the sails of which are horizontal, and are more easily driven about, and will turn what way soever the wind blows.

In the Philosophical Transactions for the year 1766, Mr. A. Brice describes a method which has been successfully practised by himself, of measuring the velocity of the wind by means of that of the shadow of clouds passing over the surface of the earth.

Mr. d'Ons en Bray invented a new anemometer, which of itself expresses on paper not only the several winds that have blown during the space of twenty-four hours, and at what hour each began and ended, but also the different strength and velocities of each. Vide Mem. Acad. Scienc. an. 1734, p. 169. For other instruments of this kind, and their use, see WIND-*Gage*.

ANEMOSCOPE, derived from ανεμος, *wind*, and σκεπτομαι, *I consider*, is sometimes used for a machine invented to foretel the changes of the wind. For this purpose it should consist of an index moving about a circular plate, like the dial of a clock, on which the 32 points of the compass are drawn instead of the hours. The index, pointing to the divisions in the dial, is turned by an horizontal axis, having a handle-head at its outward extremity. This handle-head is moved by a cog-wheel on a perpendicular axis; on the top of which is fixed a vane, that moves with the course of the wind, and gives motion to the whole machine. The whole contrivance is very simple, and nothing is required in the construction, but that the number of cogs in the wheel and rounds in the trundle-head be equal; because it is necessary, that when the vane moves entirely round, the index of the dial should also make a complete revolution. An anemoscope of this kind is placed in one of the turrets of the Queen's palace. An account of an anemoscope contrived by Mr. Pickering, may be seen in the Phil. Transf. vol. xliii. pl. II. p. 9; and another described by Mr. Martin, in his Philos. Britan., vol. ii. p. 211. See ANEMOMETER and WIND GAGE.

It has been observed, that hygroscopes made of cat's-gut, &c. prove very good anemoscopes; seldom failing, by the turning of the index about, to foretel the shifting of the wind.

The anemoscope used by the ancients seems, by Vitruvius's description of it, to have been intended rather to shew which way the wind actually blew, than to foretel into which quarter it would change.

Otto de Guerie also gave the title anemoscope to a machine invented by him, to foretel the change of the weather, as to fair and rain. It consisted of a wooden little man, who rose and fell in a glass tube, as the atmosphere was more or less heavy.—Accordingly, M. Comiers has shewn, that this anemoscope was only an application of the common BAROMETER. See WIND.

The anemoscope of Vaeroe is famous. It is made of the bird *lunde*, whose feathers are picked, the skin stripped off, *viscera* taken out, and the skin in this state drawn a-new over the bones; this being hung up in the chimney, is said always to direct its bill to the point from whence the wind is like to blow. Ephem. Acad. N. C. Dec. 3. An. 9. App. 245.

Antimony

ANTIMONY, Στιμμι, Στιμμις γυναιχειον, Gr. *Stibium Jarbason*, Lat. *Spiessglas, Spiessglanz*, Germ. *Spitsglas*, Swed. *Spidsglas*, Dan. *Pisgotz*, Hung. *Antimoine*, Fr. *Antimonio*, Ital. *Antimonja*, Ruff. *Proteus, leo ruber, plumbum nigrum, balneum regis, lupus metallorum*, Alchem.

Antimony is a brittle metal, of a brilliant white colour; fusible at a moderate red heat; and at a higher temperature, with access of air, it exhales a white inodorous vapour. It is soluble in nitro-muriatic acid, and precipitable from its solution of a white colour by distilled water, and of a deep brick-red by sulphuret of ammonia (volatile liver of sulphur.)

§ I. *Ores of Antimony.*

The antimonial ores have not as yet been analysed with sufficient accuracy to clear up all doubts as to the nature of their contents; an arrangement of them must, therefore, as yet principally depend on their external characters. We shall follow the example of Weidenmann, Emmerling, &c. in dividing them into several species, though probably the whole may be reduced to the native, the sulphurated, and the oxydated.

Sp. I. Native antimony. *Gediegen spiessglas*, Germ. *Antimonium nativum*, Werner. *Antimoine natif, & A. blanche ou arsenicale*, Delisle, Hauy, and Born.

Has a light tin-white colour, with an occasional shade of yellow. Occurs massive, disseminated, or kidney-shaped. Is internally of a brilliant metallic lustre. Its fracture is either strait or curved foliated. The fragments are usually large or small grained; seldom conchoidal. It is soft, approaching to half hard, and of considerable specific gravity.

It melts with ease on charcoal before the blowpipe, exhaling a white arsenical fume, and readily amalgamates with mercury.

By the analysis of Mongez the younger, it appears to be a native alloy of antimony and arsenic, in the proportion of about 96 of the former to 4 of the latter.

Native antimony is a mineral of very rare occurrence; it was first found in 1748, by Schwab, in the silver mines of Sahla in Sweden, with a gangue of calcareous spar; and has since been detected by Sage imbedded in quartz in the mines of Allemont in Dauphiné.

Sp. II. Sulphurated A.—Grey antimonial ore. *Graues glaserz*, Germ. *Mine d'Antimoine grise ou sulfureuse*, Delisle. *Antimoine sulphuré*, Hauy.

Of this ore there are three varieties, the compact, foliated, and striated.

Var. 1. Compact. *Dichtesgraues spiessglaserz*, Germ. *Antimonium mineralizatum griseum densum*, Werner.

The colour of this is lead-grey, passing into steel-grey, and tarnishes blue or purple on exposure to the air. It occurs massive or disseminated. Is of a metallic lustre, shining or little shining. Its fracture is small-grained uneven. It flies, when broken, into irregular blunt-cornered fragments. Is soft, gives a bright metallic streak, and is of considerable specific gravity.

It melts with great ease before the blowpipe, and burns with a blue flame, exhaling a copious white sulphureous vapour.

It is the scarcest of the sulphurated antimonial ores, and is found principally with quartz and spathose iron ore at Braunsdorf in Saxony, Goldkvonach in Bayreuth, Auvergne in France, and Majurka in Hungary.

Var. 2. Foliated. *Blättriges graues spiessglaserz*, Germ. *Antim. mineraliz. griseum lamellosum*, Werner.

This differs from the former variety in the following particulars. Colour, light steel-grey. Fracture fine grained foliated, sp. gr. 4. 36. Occurs in quartz at Braunsdorf, and at Nagyag in Hungary.

Var. 3. Striated. *Strahliges graues spiessglaserz*, Germ. *Antim. mineraliz. gris. radiatum*, Werner.

Its colour is light steel-grey, passing into a blackish grey, azure blue, golden yellow, and other splendid iridescent tints. It occurs disseminated, or in glandular mamillated and stalactitic masses or crystallized. The primitive form of its crystals has not yet been ascertained. Hauy has shewn that they are most easily and neatly divisible in one direction only, parallel to their axes; other natural joints are, however, discernible by the varying reflection of light from these surfaces when held before a candle. The only crystalline form that has hitherto been determined, is a compressed hexahedral prism, terminated by obtuse tetrahedral pyramids with trapezoidal surfaces (*antimoine sulfuré sexoctonal* of Hauy). See crystallographical plates, *fig.* 206. Incidence of *n* on *s* 134°; of *l* on *l'* 106° 30'; of *l* on *s* 146°. Born also mentions specimens from Hungary and Norway of truncated tetrahedral prisms. The surface of the crystals is generally marked longitudinally, with delicate striæ, and possesses much lustre. The internal lustre both of the amorphous and crystallized kinds is metallic and bright, or little shining. Its fracture is striated either broad or narrow, radiating, diverging, or implicated. When broken, it flies into irregular prismatic, or long granular fragments. Is soft and brittle. Specific gravity from 4.13. to 4.51. Its component parts, according to Bergman, are,

74 antimony,
26 sulphur,

———

100

The Hungarian antimony also contains a small variable proportion of gold.

This is the commonest of all the antimonial ores: it is procured at Kremnitz and Telsobanya in Hungary, at Draviza in the Banat, Braunsdorf in Saxony, the Black Forest in Swabia, Pereta in Tuscany, Lubillac in Auvergne, and Cornwall in England; also in Spain, Mexico, and Siberia. The splendid iridescent specimens come principally from Hungary.

Sulphurated antimony is sometimes confounded with oxyd of manganese; it may, however, be easily distinguished by the great ease with which it is fusible even in the flame of a common candle: it differs also from native antimony in exhaling, when heated, a sulphureous, and not an arsenical odour; in being of a darker colour, and leaving a dark grey trace when rubbed on paper.

It is found, for the most part, in primitive mountains, in micaceous schistus, and clay porphyry, mixed with pyrites and oxyds of iron: the gangue is sulphated barytes in Hungary, but elsewhere, for the most part, quartz; also, though rarely, chalcedony fluor and calcareous spar.

Sp. III. Plumose antimony. *Federerz, silber federerz*, Germ. *Mine d'argent grise antimoniale*, Delisle. *Antimoine sulphuré argentifere*, Hauy. *Antimonium plumosum mineralizatum argentiferum*, Born. *Antimonium mineralizat. griseum plumosum*, Werner.

The colour of plumose antimony is steel-grey, passing into greyish black, lead, or smoak grey: by exposure to the air, it tarnishes to an iridescent blue or yellow. It occurs in slender minute capillary crystals investing the surface of quartz and other minerals with a delicate brittle down or wool: the crystals are sometimes scarcely visible to the naked eye, and so implicated with each other, as to appear like an amorphous crust. According to Delisle, the form of the crystals is that of a compressed hexahedral prism, terminated by dihedral summits with pentagonal faces; the longitudinal striæ, however, are generally so strongly marked as to obscure the sides of the prism. Its lustre is semi-metallic, more or less glimmering. The fracture is confusedly fibrous, and the fragments are indeterminate. It is brittle: sp. grav. 3.57. Before the blowpipe it emits a smoke that deposits a white and yellow powder on the charcoal, and the residuum then melts into a black slag. No accurate analysis has yet been made of it; but, according to Bergman, it consists of antimony, iron, arsenic, sulphur, and sometimes silver.

This substance is ranked by many mineralogists among the silver ores; but improperly, as the proportion of silver is casual and variable, and never exceeds 3½ or 4 per cent.

It is met with in the Saxon mines, especially that of Himmelfurst near Freyberg; also at Stollberg in the Hartz, and Schemnitz in Hungary.

Sp. IV. Red antimony. *Rothes spiessglaserz*, Germ. *Soufre doré natif strié*, et *Kermes mineral natif*, Delisle. *Antimoine hydrosulfuré*, Hauy. *Antimonium auripigmento mineralizatum*, Cronstedt. *Antimonium mineralizatum rubrum*, Werner.

The colour of red antimony is a deep crimson approaching to blood red, sometimes, though seldom, clouded with iridescent blue. It occurs generally in minute short hair, or needle-form crystals, radiating or implicated: sometimes also it is found massive or disseminated. Its lustre is vitreous, little shining. Its fracture is fine, and irregularly diverging fibrous. It is opaque, brittle but somewhat elastic: sp. grav. 4. to 4.7.

Before the blowpipe it melts easily and evaporates, exhaling a slight sulphureous odour.

The only mineral with which it is liable to be confounded is the red silky oxyd of copper: this last, however, is of a brighter colour, and dissolves with effervescence in nitrous acid, giving it a green tinge; the red antimony, on the contrary, is not dissolved, but becomes covered with a whitish crust. No accurate analysis has yet been made of this ore; from its colour it was formerly supposed to contain arsenic and sulphurated antimony: according to Sage, however, it is a native mineral kermes. Thus much is certain, that it is met with in the crevices, and investing the surface of the common sulphurated antimony, and appears to be this in an advanced state of natural decomposition: the amorphous or massive variety is frequently studded with small crystals of native sulphur, in the form of rhomboidal octahedrons.

It is met with at Braunsdorf in Saxony, Malazka and Cremnitz in Hungary, and Allemont in Dauphiné.

Sp. V. White antimony. *Muriated antimony*, Kirwan. *Weiss Spiessglaserz, spiessglanzspath*, Germ. *Muriate d'antimoine*, Born. *Antimoine oxydé*, Hauy. *Antimonium mineralizatum album*, Werner.

The colour of white antimony passes from snow-white through greyish and yellowish white into ash grey. It is seldom found massive, often radiating like zeolite, but generally crystallized in small and long quadrilateral prisms or rectangular tables, which are accumulated together in bundles or cells. The surface of the crystals is plain, or longitudinally striated, and bright shining or specular. Internally this mineral is much shining, or shining with a vitreous lustre passing into pearly. Fracture strait foliated. It flies when broken into irregular, not particularly sharp cornered fragments. Is translucid, soft, brittle, and heavy.

In whole crystals it decrepitates before the blowpipe; but when powdered, it melts quietly and without difficulty, giving out a white smoak, and by degrees totally evaporates. Between two coals it is reducible to the metallic state.

From the analysis of Klaproth, it seems to consist of antimony and muriatic acid; but the acicular variety from Dauphiné afforded Vauquelin,

86 oxyd of antimony,
3 oxyd of iron and oxyd of antimony,
8 silex,
3 loss.

———

100

This beautiful, but uncommonly rare fossil, was first discovered in 1782, by Mongez the younger, at Allemont in Dauphiné, mixed with native antimony; afterwards, in 1787, by Rössler at Przibram on the surface of galena: it occurs also at Malazka in Hungary, with the red and sulphurated antimony.

Sp. VI. Yellow antimony. *Supposed phosphorated antimony*, Kirwan. *Phosphate d'Antimoine*, Fr. *Gelb Spiessglaserz*, Germ. *Antimonium mineralizatum flavum*, Werner.

The colour of this is orange or wax yellow, or yellowish white, passing into black when tarnished. It occurs in long striated needleform crystals, or quadrilateral tables. It is shining, and when black has a metallic lustre. Is soft, flexible, and heavy.

Before the blowpipe it neither flames nor smokes, but melts easily into a brittle slag, containing a small tin-white

bead of metal. It has not been analysed. This mineral was first discovered by Count Rasumawsky, in a vein of sulphurated antimony at Faucigny in Savoy, and has since been found at Malazka in Hungary.

Sp. VII. Antimonial ochre. *Spiessglasokker*, Germ. *Antimonium ochraceum*, Werner.

Its colour is straw or lemon yellow, and yellowish grey. Occurs massive, disseminated or investing. Is dull; of a fine earthy fracture; soft, brittle, and heavy.

Before the blowpipe it becomes white, volatilizes, but does not melt. It effervesces strongly with borax, and is partially reduced. It has not yet been analysed, but is supposed by Karsten to be an oxyd of antimony.

It is found at Bräunsdorf near Freyberg, and in Hungary, mixed with sulphurated and red antimony.

Emmerling, vol. ii. Wiedenman, Handbuch, &c. Lenz, Versuch, &c. vol. ii. Hauy, Traité de Mineralogie, vol. iv. Delisle, Crystallographie, vol. iii. Kirwan's Mineralogy, vol. ii.

§ 2. *Assay and Analysis of Antimonial Ores.*

All the antimonial ores are easily reducible before the blowpipe on charcoal; and by a continuation of the heat, they exhale a dense smoak of a white or yellowish colour, with little or no arsenical odour, and deposit yellowish flowers, or white needleform crystals, on the surface of the charcoal: these appearances are, however, liable to considerable modification on account of the variable proportion or lead, arsenic, sulphur, &c. that are usually mixed with the antimony. A more certain, therefore, though not so expeditious a method of ascertaining the presence of this metal, is to reduce 200 grains of the ore to fine powder, and digest it in a moderately diluted nitro-muriatic acid, in which the nitrous is not more than one-third of the muriatic part. The clear liquor, after slow digestion for an hour, is to be decanted and reduced by evaporation to about half its bulk, and then poured into a large quantity of distilled water: a copious white precipitate immediately takes place of antimonial oxyd, which when edulcorated and mixed with an equal weight of crude tartar, is to be put into a small lined crucible fitted with a cover, and by a moderate red heat the oxyd will be reduced into a metallic button.

The analysis of antimonial ores presents no particular difficulties, except such as are common to all minerals in which arsenic enters. The following are the substances which have been found mixed with antimony, *viz.* iron, silver, lead, copper, arsenic, and sulphur; to which must be added, silex and alumine, as composing the stony gangue, which cannot always be entirely separated previous to analysis.

(*a*) Let 500 grains of the ore be reduced in an agate mortar to an impalpable powder, and afterwards mixed in a flask with 1500 grs. of pure nitrous acid of sp. gr. 1.25, and 1000 grs. of distilled water; digest the mixture at a temperature considerably less than boiling, for an hour, then pour off the clear liquor, and add nitrous acid equal to half the quantity first used; digest this for a few minutes, and add by degrees, during the remainder of the digestion, half as much distilled water as acid; then pour off the clear liquor, and wash the residue with distilled water.

(*b*) Add together the two nitrous solutions and the washings, and drop in a saturated solution of muriated soda as long as any precipitate takes place, and allow it to stand for a few hours; pour off the liquor, and boil the precipitate in a little distilled water; filter and edulcorate. Add the washings to the liquor.

(*c*) The precipitate (*b*), consisting of muriated silver, and probably a little arsenic, being dried in a heat just inferior to its fusion, is to be weighed, and reduced in a small crucible by twice its weight of pearlash: 75 parts of silver denote 100 of muriated silver, and if the produce of metal is less than that obtained by calculation, the deficiency may be set down as arsenic.

(*d*) The nitrous solution (*b*), containing a great excess of acid, is to be reduced to only a slight excess by the addition of potash or soda; and is then to be treated with nitrated barytes for sulphuric acid: the sulphat of barytes thus produced, contains the sulphur of the ore oxygenated by the nitrous acid. This being separated, add a saturated solution of sulphated soda, as long as any precipitation takes place. This is sulphated lead.

(*e*) The residue of solution (*d*), being evaporated to dryness, is to be mixed with soap, and heated in a subliming flask, the arsenic will thus be obtained in a metallic state.

(*f*) Upon the insoluble residue (*a*) digest two or three ounces of nitro muriatic acid, composed of nitrous acid 1, muriatic acid 5, water 3. By this the antimony, iron, and copper will be dissolved, together with a little alumine and silex. Separate this from the undissolved residue, and pour the liquor into three or four times its quantity of distilled water, and the oxyd of antimony will be precipitated. Separate this by filtration, wash, and add the washings to the other liquor: 130 parts of oxyd of antimony well dried denote 100 of metal.

(*g*) Evaporate the fluid (*f*) to a small bulk, and supersaturate it with caustic ammoniac, the iron and earths will be precipitated, and the copper will be held in solution, giving it a blue colour. Separate the precipitate by a filter; and add sulphuric acid to the ammoniacal liquor till it becomes acidulous, then precipitate the copper by a bar of clean iron.

(*h*) The precipitate (*g*) being digested with a little caustic potash, the silex and alumine will dissolve, leaving the oxyd of iron behind.

(*i*) The undissolved residue of (*f*) being dried and weighed, is to be ignited to drive off the sulphur, the quantity of which is denoted by the loss of weight after ignition. What remains is earth and a few atoms of metallic oxyd, which being fused with black flux, will reduce the oxyd, and render the earths soluble in water.

(*k*) The sulphated lead (*d*) is to be reduced by fusion with tartar, and the oxyd of antimony also by the same method: being then weighed separately, as much pure lead is to be added as will make the lead twice the weight of the antimony. The metals being melted together are to be divided into two equal parts, and subjected to cupellation; if any silver remains, its amount is to be added to that of (*c*). Bergman's Ess. Klaproth's Analytical Essays. Kirwan's Mineralog. vol. ii.

§ 3. *Reduction of Antimonial Ores.*

The grey or sulphurated antimony is the only one of this metal that is found in sufficient abundance for the purposes of manufacture, and the treatment that it undergoes is extremely simple. The larger pieces of the earthy or stony matter of the gangue being first picked out, the remainder is coarsely bruised, and subjected to a low red heat in close vessels: the sulphurated metal then melts on account of its very easy fusibility, leaving the impurities behind. This process is usually performed in a crucible, whose bottom, perforated with a number of small holes, is inserted into an-

other crucible. (See Chemiſtry, Plate iv.) A. B. *fig.* 15, or connected with the lower crucible by means of a pipe, *fig.* 16. In each apparatus the ore is put into the upper crucible, which ſerves the purpoſe of a filter, by detaining the ſtony impurities, while the melted metal flows into the lower receptacle. *Fig.* 17, 18, 18, 19, 20, 21, 22, are plans and ſections of the furnaces generally made uſe of. This method, however, of extracting the ore is far from being the moſt economical poſſible, on account of the length of time neceſſary to charge a multitude of crucibles, the expence of replacing thoſe that are broken, and the extra quantity of fuel required when the ore is not in immediate contact with the flame. On this account ſome of the founderies in Hungary and France have altogether diſcarded the crucibles, and melt the antimony in maſs by a reverberatory furnace, taking care to keep the ſurface of the metal covered with charcoal to prevent oxydation. *Fig.* 23 and 24 are a plan and ſection of ſuch a furnace. The rough ore being placed in the bed A, and covered with charcoal, is gradually brought to a ſtate of fuſion; and the plug at B being then withdrawn, the melted metal flows into the receptacle C. *Fig.* 25, 26, repreſent another kind of furnace for the ſame purpoſe made uſe of at Ramée in La Vendée. The ſulphurated antimony thus obtained is remelted, and caſt into loaves or cakes, forming the common or crude antimony of the ſhops.

§ 4. *Regulus of Antimony.*

The ſulphurated ore of the preceding ſection having been long known by the name antimony, the term regulus of antimony was employed to deſignate the pure metal: in the reformed nomenclature, on the other hand, the former of theſe ſubſtances is called ſulphuret of antimony, and the latter ſimply antimony. This ambiguity it is of conſequence to be aware of, and we ſhall endeavour to avoid it as much as poſſible by uſing the term regulus of antimony wherever by ſo doing the ſenſe may be made clearer.

The ſubſtance from which the regulus is prepared, whether in the large way for the purpoſes of commerce, or in the laboratory, is univerſally the native ſulphuret. This conſiſts of antimony and ſulphur in the proportion, according to Bergman, of 74 of the former to 26 of the latter. Numerous methods have been propoſed by different chemiſts for the ſeparation of the metal, all of which may be conveniently arranged under the three following general heads. I. Reduction by roaſting. II. Reduction by ſcorification. III. Reduction by dry parting or precipitation.

I. Reduction by roaſting.

The native ſulphuret of antimony being previouſly ſeparated by fuſion from all earthy impurities, as deſcribed in § 3, is to be pulverized and ſpread thinly on the floor of a reverberatory furnace or muffle, to be freed from its ſulphur by roaſting. At the commencement of the proceſs the fire muſt be managed with particular care, and the temperature ought ſcarcely to be greater than what is neceſſary for the fuſion of tin, otherwiſe the antimony will clog, and even melt, ſo as to require being removed from the fire, and again pulverized: as ſoon as the fumes of ſulphur become viſible to the eye, in the form of a light lambent blue flame, it is a proof that the heat is ſufficient; and the ore ſhould now be continually ſtirred with a tobacco-pipe, or any other earthen rod. In a ſhort time the antimony will begin to oxydate, and aſſume a greyiſh earthy appearance; the fire may then be raiſed a little, to haſten the evaporation of the ſulphur; and thus the operator may go on gradually increaſing the heat as the ore will bear it; and continually ſtirring it, ſo as to expoſe freſh ſurfaces to the air. When the ore is moderately red-hot, and ceaſes to give out a ſulphureous vapour (which will not be till after ſome hours), the roaſting is finiſhed. By this means an aſh-grey oxyd is obtained; ſtill, however, not entirely free from ſulphur, weighing from 30 to 36 per cent. leſs than the original ſulphuret.

In order to obtain the regulus from this grey oxyd, the common way is to mix it with half its weight of crude tartar, and expoſe it in a covered crucible to a full red-heat: the tartar will thus be decompoſed, its carbonaceous part ſerving to deoxygenate the antimonial oxyd; and its alkaline baſe combining with the ſulphur ſtill contained in the ore, forms ſulphuret of potaſh, by which a portion of antimony is held in ſolution, while the reſt of the regulus, by its ſuperior ſpecific gravity, unites into a maſs at the bottom of the crucible. The quantity of regulus obtained by this means in the large way, is from 66 to 70 per cent. on the oxyd; but the produce depends eſſentially on the accuracy with which the roaſting has been performed: if much ſulphur ſtill remains in the oxyd, a large proportion of the metal will be diſſolved in the ſulphurated alkaline ſcoria. Kunkel's method appears to be more economical, and better in every reſpect: he mixes the roaſted oxyd with oil or fat and a little powdered charcoal, puts the mixture into a crucible to melt, and as ſoon as the regulus begins to ſhew itſelf, injects by degrees ſome powdered nitre, in the proportion of an ounce to a pound of antimony: the matter in thin fuſion being poured out, a pure regulus is obtained in much greater quantity than by the common way. Moſt of the ſulphurated ores, as thoſe of lead and copper, are reduced to the metallic ſtate after roaſting by a ſimple carbonaceous addition, by which means the product of metal is greater than if an alkaline flux was made uſe of, and the whole expence of the flux is ſaved. Induced, therefore, by theſe motives and analogies, a ſeries of experiments was undertaken by Haſſenfratz, Vauquelin, and Buillon la Grange, to obtain the regulus of antimony by cheaper means than the uſe of tartar or nitre. For this purpoſe different parcels of the roaſted grey oxyd were mixed with charcoal powder, with tallow and with pitch, and expoſed in covered crucibles to a reducing heat; being then withdrawn, and the contents of each examined, nothing was found in the crucibles but a little carbonaceous matter, and a few minute globules of antimony, the reſt being evaporated. Some grey oxyd was then mixed with, 1. equal parts of lime, alumine, and ſilex; 2. equal parts of ſulphat of barytes, chalk and clay; 3. with common ſalt; 4. with ſulphat or ſoda; and the materials being ſtrongly heated, they were all found converted into yellow glaſſes, but not a particle of regulus could be perceived. The above four mixtures, with ſome charcoal rubbed up into them, were next treated as before: vitreous ſcoriæ were obtained, but no greater quantity of regulus than when charcoal alone was made uſe of. Laſtly, ſome of the ſame grey oxyd being fluxed with half its weight of tartar, yielded a perfect button of pure antimony. Hence it appears, that potaſh, and probably alkalies in general, exert ſome ſpecific action on antimonial oxyd, which induces it to become much more fixed while converting into regulus, than when mere carbonaceous matter is employed.

II. Reduction by ſcorification.

This, although the moſt expenſive and inaccurate method of procuring the regulus of antimony, is generally preferred in the laboratory to every other on account of its expedition. For this purpoſe the antimonial ſulphuret is reduced to a fine

powder, and mixed with nitre and tartar; a crucible being then made red hot, successive spoonfuls of the mixture are gradually projected into it till the vessel is nearly filled; being then covered, and a full red heat applied for half an hour, the contents are either poured out into a greased iron cone, or suffered to cool in the crucible; a pure regulus is thus obtained, covered with a mass of saline scoriæ. In this process the acid of the nitre is decomposed, and is employed in acidifying the sulphur and partly oxydating the antimony, while the carbonaceous matter of the tartar serves to deoxydate the metal, and in some degree also to decompose the sulphuric acid; hence the scoriæ consist of the potash of the nitre and tartar, partly united with sulphuric acid, forming sulphat of potash, and partly with sulphur, forming sulphuret of potash, which last also holds in solution a considerable proportion of the antimony.

If the quantities of nitre and tartar are large compared with that of the crude antimony, nearly the whole of the metal will be taken up by the scoriæ. According to Lemery, sixteen ounces of sulphurated antimony, mixed with the same weight of nitre and also of tartar, yielded no more than five ounces and a half of regulus. Whereas sixteen ounces of crude antimony, twelve ounces of tartar, and six ounces of nitre, afforded six ounces and one dram of regulus. The usual proportions are four parts of crude antimony, with three parts of tartar, and one and a half of nitre. Some advise to detonate the nitre and tartar together, before the antimony is added, but this is decidedly a bad way, as the use of the nitre is not to alkalize the tartar, but to oxygenate the sulphur. A greater proportion of regulus than usual would probably be obtained by mixing the antimony and nitre alone, and not adding the tartar till after the detonation had taken place.

III. Reduction by precipitation.

This is effected by fusing the antimonial sulphuret with any other metal whose affinity for sulphur is greater than that of antimony, in which case the sulphur combines with the added metal, while the regulus of antimony collects in a button at the bottom of the crucible. The metals capable of thus decomposing the sulphurated antimony are iron, copper, lead, silver, and tin, whence originated five varieties of antimonial regulus, known among the alchemists by the names of martial, venereal, saturnine, lunar, and jovial. As equal parts of these metals require different quantities of sulphur for their saturation, a greater or less proportion of them is necessary for a given weight of crude antimony: thus two parts of this last substance are decomposed by one part of iron, by two parts of copper, or by four parts of lead.

In order to prepare the martial regulus (for all the others are now became obsolete), a number of formulæ are given by Lemery, Beaumé, and other practical writers, the relative merits of which can only be duly appreciated by a comparison of the quantity and purity of the regulus with the expence of time, of fuel, and of nitre, required in its preparation. The following are those which seem best worth notice:

1. Take eight ounces of horseshoe nails, and heat them nearly to whiteness in a crucible, then add, by degrees, sixteen ounces of coarsely pulverized antimonial sulphuret; cover the crucible and keep up the fire; in a few minutes the mixture will be in perfect fusion, at which time, add little by little, three ounces of nitre, a slight detonation will take place, and the whole will be brought to a state of perfect fusion; then pour it into an iron cone, heated and greased, and strike the sides of it gently as the mass becomes solid to favour the precipitation of the regulus. When cold it will be found to consist of a button of antimony, weighing about ten ounces, covered with an alkaline ferruginous scoriæ, from which it is readily separated by a blow with a hammer. This regulus, however, is far from pure, containing both iron and a little sulphur; it is therefore to be remelted, and mixed while in fusion with two ounces of crude antimony and three ounces of nitre; after all detonation has ceased, pour it into an iron cone as before; and separate the regulus from the scoriæ. Remelt the regulus and project upon it by degrees three ounces of nitre. Separate this regulus from the scoriæ, and melt it again once more with three ounces of nitre; heat it strongly and rapidly, and pour the whole into a cone; there will be obtained about eight ounces of a beautiful stellated regulus, covered with yellowish white scoriæ. In this process the whole of the materials employed are eighteen ounces of crude antimony, eight ounces of nails, and twelve ounces of nitre; four separate fusions are required, and the product is eight ounces of regulus.

2. Pulverize and mix together 16 ounces of crude antimony, 12 ounces of tartar, 10 ounces of nitre, and eight ounces of iron filings; project it by degrees into a red hot crucible, a strong detonation will take place, and the mass will enter into fusion; keep it at a full heat for a few minutes, and then pour the whole into an iron cone; when cold, there will be found beneath the scoriæ a pure stellated martial regulus, weighing about six ounces.

3. Heat in a crucible till they are white hot, five ounces of horseshoe nails, and then add 16 ounces of crude antimony, coarsely pounded; the two will presently melt down together, and as soon as the mass is in very liquid fusion, project at several times one ounce of pulverized nitre; during each projection there will be a detonation, and when the last has ceased, increase the heat for a few minutes, and then take out the crucible and allow it to cool gradually; there will be found at the bottom of the vessel a perfectly pure martial regulus.

In the reduction of antimonial sulphuret by iron, the success of the experiment depends much upon the temperature; a high heat briskly applied, and of short continuance, so as to bring the whole into very liquid fusion, is far preferable to an inferior heat of longer continuance: since the regulus separates more completely from the scoriæ, and the proportion of metal, lost by evaporation, is not nearly so considerable.

The antimony obtained by roasting or scorification, by proper care, may be rendered absolutely pure; but the martial regulus, though purified so as to exhibit the stellated appearance on its surface, which is usually reckoned characteristic of purity, is, in fact, an alloy of antimony and iron; hence it is harder and more difficultly amalgamable than the former; and when reduced to fine powder, is, according to Lemery, attracted by the magnet.

§ 5. *External Characters and Physical Properties of Reguline Antimony.*

This metal, when perfectly pure, is of a dusky white colour, between that of tin and iron; it appears to be absolutely destitute of ductility, and may easily be reduced in a mortar to a fine powder; it is moderately hard, and may be cut without much difficulty by a common knife. Its fusibility is not quite so great as that of zinc, since it requires to be made red hot before it flows. Its specific gravity, according to Bergman, is 6.86; but by the later experiments of Brisson, amounts to 6.7021. Its fracture is usually broad foliated, but sometimes the facets are so minute as to give it almost a granular appearance; in general the slower it is cooled, the broader will be the plates of which it

is compoſed, but this rule is not without its exceptions. Antimony is one of the moſt eaſily cryſtallizable of all metals, and this tendency is ſhewn in a ſtriking manner by the appearance of a radiated ſtar, or of pinnated leaves, like thoſe of fern, with which the convex ſurface of a maſs of antimony that has been allowed to cool ſlowly is generally covered. It was this circumſtance that induced the alchemiſts to pay ſo much attention to antimony; by their heated imaginations every thing ſingular was conſidered as a type or myſterious hint, and thus confounding ſacred with profane, they denominated this appearance, which in truth is only the reſult of a confuſed cryſtallization, the eaſtern ſtar that was to conduct the ſages (themſelves) to the cradle of their king, i. e. to the method of making gold, the king of metals. Theſe rays or branches are merely ſuperficial as Lemery demonſtrated, by making tranſverſe ſections of various maſſes of ſtellated regulus. If a crucible, furniſhed with a plug at the bottom, is filled with melted antimony, and the fluid part allowed to run out by withdrawing the plug as ſoon as a cruſt is formed on the ſurface of the metal, there will be found under the cruſt various cryſtalline groups, conſiſting of cubes, of lnegthened rectangular parallelepipeds, or ramifications, made up of ſmall octohedrons implanted in each other, and frequently aggregated into a trihedral pyramid, with furrowed ſides. The primitive cryſtalline form of antimony has hitherto eluded the ſagacity of Hauy: it is diviſible at the ſame time parallel to the faces of a regular octohedron, and of a rhomboidal dodecahedron.

§ 6. *Oxyds of Antimony.*

The action of air and moiſture at the uſual temperature upon reguline antimony is ſcarcely perceptible, as it remains a long time without even tarniſhing, and the oxydation is never more than merely ſuperficial. By a low red heat, however, and the contact of air, this metal is gradually converted into a greyiſh white oxyd, volatile at a higher heat, and capable of being more completely oxygenated. When antimony is brought quickly to a bright red heat, and then expoſed to the air, is is rapidly converted into a white oxyd, which being volatile, exhales in the form of a denſe ſmoak from the ſurface of the melted metal, and condenſes in the upper and cooler part of the crucible into beautiful cryſtalline needles of a ſnowy or ſilvery white; which have obtained the name of argentine flowers of antimony, or ſnow of reguline antimony. As this cryſtallized oxyd is not eaſily obtained in a common crucible, we ſhall mention the method of preparing it as given by Beaumé. "Place a wide cylindrical earthenware tube cloſed at one end in a wind furnace, ſo that it ſhall remain in a ſlanting direction, with the open end protruding a little way through a hole or door in the ſide of the furnace; and to prevent the inſide of the tube from being too much cooled, an earthenware ſtopper muſt be prepared to fit looſely into the open mouth of the tube.— The apparatus being properly put together, light the fire, and when the bottom of the tube is red hot, introduce the antimony in ſmall pieces, and cloſe the mouth of the tube with the ſtopper. The metal being melted, will begin in a ſhort time to ſmoke, and the cryſtalline oxyd will be depoſited in the upper part of the tube, from which it may be ſcraped from time to time with a clean iron ſpoon. The firſt portions are generally yellowiſh on account of a ſmall quantity of ſulphur contained in the metal; this, however, is ſoon burnt off, and the ſucceeding flowers are of a pure brilliant argentine white colour." Although antimony is not combuſtible at ſo low a temperature as zinc, yet, at a white heat, with acceſs of air, it burns with a white flame, throwing out copious vapours of white oxyd. Another pretty experiment on the inflammation of antimony, was diſcovered accidentally by Cit. Gillet. Place a ſmall piece of antimony on a bit of charcoal, and fuſe it by the blowpipe; when it is boiling hot, ſhake it gently out ſo that it may fall three or four feet through the air; it preſently divides into a few globules, which immediately take fire, and explode when they reach the ground like fireworks.

The cryſtalline oxyd, like the other white oxyds that we ſhall have occaſion to notice in the next ſection but one, appears to be a ſaturated combination of antimony and oxygen, in the proportion, according to Thenard, of 80 of the former to 20 of the latter; in many of its properties it reſembles the metallic acids; it is ſoluble, though but ſparingly, in water, has a decided taſte, forms a cryſtallizable ſalt with potaſh, from which it may be ſeparated by the action of any of the ſtronger mineral acids. When heated by itſelf in a porcelain tube, it may be reduced nearly to the metallic ſtate; the firſt impreſſion of the fire converts it into a yellow oxyd, very eaſily fuſible into glaſs, and containing 0.19 of oxygen; afterwards, as the heat increaſes, it aſſumes a reddiſh brown tint, and holds only 0.16 of oxygen; at length it arrives at the ſtate of black oxyd, wanting only to be deprived of 0.02 of oxygen, to return to the metallic form. Oxyd of antimony, by haſty fuſion in a crucible, is converted into a vitreous maſs, which, when tranſparent, is of a yellowiſh orange colour, and is called *glaſs of antimony;* and when opaque, is of a brown colour, and has hence obtained the name of *liver of antimony.* Theſe preparations, however, muſt not be confounded with the glaſs and liver of antimony, as procured from the ſulphuret of this metal.

§ 7. *Action of Acids on Antimony.*

1. The *ſulphuric acid,* when cold, appears to exert no action on antimony; but when boiling hot, it is decompoſed by this metal, a copious extrication of ſulphureous acid gas takes place, accompanied by violent efferveſcence; and if the mixture is diſtilled to dryneſs in a retort, a ſmall quantity of ſulphur ſublimes, and a maſs of white antimonial oxyd is at the bottom of the veſſel. When the proceſs is ſtopped ſhort of deſiccation, there remains in the retort a white, bulky, ſoft, and moiſt maſs, and this, when waſhed with a little water, occaſions a copious depoſit of white oxyd, while the clear liquor becomes diluted ſulphuric acid, holding in ſolution a ſmall portion of antimony; a larger quantity of water added to this liquor, precipitates what remains of antimonial oxyd. The action of heat alſo has the ſame effect, for while evaporating it becomes turbid without forming cryſtals; the ſame takes place on the mixture of any alkaline ſolution. If the unwaſhed ſulphated oxyd of antimony is mixed with common ſalt and diſtilled, the reſult is oxymuriat, or butter of antimony.

2. *Sulphureous acid,* whether hot or cold, has no effect whatever on reguline antimony; it will, however, decompoſe moſt of the acid ſalts of this metal, eſpecially that formed by muriatic acid. If ſulphureous acid is added to a ſolution of muriated antimony, a white powder is thrown down of an acrid and harſh taſte, which appears to be a true inſoluble ſulphite of antimony, decompoſable with extrication of the ſulphureous acid by the ſulphuric, or by mere heat in cloſe veſſels; the reſidue of this laſt operation is a reddiſh brown matter, ſoluble in fixed alkali, and again precipitable by the muriatic acid in form of kermes, or hydroſulphurated oxyd of antimony.

3. *Nitric acid,* eſpecially the yellow, is ſpeedily decompoſed on antimony, even in the cold. During the mutual action of theſe two bodies, a large diſengagement of nitrous gas takes place, and the metal is converted into a white oxyd ſo rapidly, as ſometimes to cauſe actual inflam-

tion. In its eager abforption of oxygen, a great analogy fubfifts between antimony and tin; for not only the nitric acid, but even the water that is mixed with it, are decompofed by the antimony; the azot of the former, and the hydrogen of the latter of thefe fluids, combine together during their nafcent ftate, and produce ammonia, which with the undecompofed acid, forms nitrated ammonia, the cryftals of which falt, thus unexpectedly occurring, have fometimes been miftaken for nitrat of antimony. If the white oxyd, refulting from this chemical action, is mingled, before it has been wafhed, with lime or cauftic alkali, ammoniacal gas will be difengaged. The greateft part of the antimonial oxyd remains uncombined at the bottom of the veffel; a very fmall quantity, however, is taken up by the fupernatant acid; but even this little is precipitated by water, by evaporation, and by mere ftanding for a few days. The white nitrous oxyd is fully faturated with oxygen, of which it contains, according to Thenars, about 30 per cent. It is confidered as one of the moft refractory and irreducible of the metallic oxyds, which it certainly is when treated with the common fluxes; but when rubbed with a little regulus of antimony, and heated in a clofe veffel, it becomes in fucceffion yellow, orange, brown, and then black; containing only about two per cent. of oxygen, as is related of the argentine flowers in the former fection.

4. *Muriatic acid*, when affifted by heat, is capable of diffolving a fmall proportion of antimony; part of this, however, is again depofited in the form of a white oxyd as the liquor cools: by evaporation it may be brought to cryftallize in fmall acicular deliquefcent needles. The oxyd of antimony is more eafily foluble in muriatic acid than the metal itfelf, and alfo in greater proportion: it cryftallizes, according to Monnet, in brilliant plates, like the boracic acid, and is decompofable by water.

5. The *oxygenated muriatic acid*, when in the form of gas, exerts a very ftriking action on reguline antimony: if this metal, previoufly reduced to a fine powder, is thrown by fmall quantities at a time into a vial filled with the acid gas, each parcel will be found to take fire, and burn with a white flame, throwing out, at the fame time, a number of bright fparks, and thus forming a moft beautiful fhower of fire. The antimony is converted into a white muriated oxyd. The liquid oxymuriatic acid changes the metal into a powdery oxyd, but holds a very fmall quantity of it in folution; no doubt on account of the great proportion of water, which even the moft concentrated liquid oxymuriatic acid neceffarily contains. If a folution of either the muriat or oxymuriat of antimony be gently evaporated nearly to drynefs, and afterwards expofed in a retort to a low fand heat, a thick oleaginous liquid will come over, that by cooling concretes into a foft mafs, called, from its confiftence, by the ancient chemifts, *butter of antimony*; the above, however, is not the actual method of preparing this falt in the laboratories; it is more expeditioufly made by taking advantage of the fuperior affinity which antimony has over mercury: for this purpofe fome reguline antimony is well mixed in a mortar with twice or two and a half times its weight of oxymuriated mercury (corrofive fublimate); during trituration, much heat is extricated, the evidence of a chemical action between the two fubftances: the mixture being put into a wide necked retort, with a fuitable receiver adapted, is expofed in a fand bath to a gentle heat. During the firft half hour, a fmall quantity of a clear liquid paffes into the receiver, which is afterwards followed by a thick liquor that concretes by cooling in the receiver, and often in the neck of the retort into a white mafs; this is the *butter of antimony*. A moderate fire is kept up till nothing more comes over, at which time the receiver is unluted, and emptied of its contents; there remains in the retort fluid mercury with fome muriated oxyd of antimony. By continuing the diftillation at a greater heat, the mercury is volatilized, and collected in a liquid ftate in the receiver. It is to be remarked, however, that there are two objections to this procefs; the one, that if the mercurial falt is in too great proportion, a little of it will rife with the butter of antimony, and be diffolved in it; the other objection is, that if too little oxymuriat is ufed, the produce will be much diminifhed, as a confiderable proportion of the antimony will be merely in the ftate of muriated oxyd. The beft way, therefore, of preparing this falt, is to mix the unwafhed fulphat of antimony (1. § 7.) with common falt and black manganefe, and diftil the whole to drynefs.

The London Pharmacopœia orders the fublimed muriat to be made thus. Mix together one part of crocus of antimony with two parts of decrepitated falt; put the mafs into a glafs retort, and add one part of fulphuric acid; then diftil, and what comes over is butter of antimony.

Butter of antimony, though folid at the ufual temperature of the atmofphere, liquefies at a very gentle heat, and by flow cooling cryftallizes in large parallelepipeds. It is intenfely cauftic, deftroying the organization both of animal and vegetable fubftances; by expofure to the air and light it becomes coloured, and deliquiates into a thick oleaginous fluid. When dropped into diftilled water, it is for the moft part decompofed, and a copious white precipitate is thrown down, which is little elfe than a perfect oxyd of antimony. This, after being wafhed and dried, forms the *powder of* ALGAROTH, or *mercurius vitæ*. The clear liquor feparated from the precipitate ftill holds a little antimonial oxyd in folution, as is obvious from a further precipitation taking place on the addition of an alkali.

Scheele has given the following method of preparing powder of algaroth, in an effay of his on this very fubject. To two parts of fulphurated antimony add three of nitre, and detonate the mixture in a hot crucible; pulverife the mafs, and ftir in one part of this to three of water, with one of fulphuric acid, and one of common falt. Let the whole digeft together for twelve hours in a fand bath, and ftrain it through a cloth; feparate the clear liquor, and add to the refidue more falt and diluted fulphuric acid, which digeft and filter as before. Mix the two liquors together, and pour them into a large quantity of boiling water; a white precipitate immediately takes place, and this, when wafhed and dried, is the powder of algaroth.

If to any quantity of fublimed muriat of antimony an equal weight of nitric acid is added, the liquor becomes highly coloured, copious orange-coloured fumes are difengaged, and a confiderable degree of heat is excited; after a while, a white magma of oxyd is depofited. If before the latter effect takes place, the liquor is evaporated to drynefs, a pure white oxyd remains behind; and this being three times more abftracted with frefh nitric acid, and afterwards heated moderately red in a crucible, affumes the appearance of a pulverulent mafs, white at the furface, and rofe-coloured beneath; this being ground in a mortar, fo that the white and coloured parts may be thoroughly mixed, is known in the fhops and old pharmacopœias by the name of *bezoar mineral*; and, in fact, is nothing more than a perfect oxyd of antimony, holding, perhaps, a very fmall portion of the acid.

6. *Nitro-muriatic acid* is the beft folvent of reguline antimony; if the acid is made moderately warm, and the metal put in by fmall pieces at a time, taking care not to

add a second till the first is completely dissolved, it may be thus charged with a considerable proportion of antimony, only a small part of which is deposited by cooling. This, however, like all the preceding antimonial solutions, is almost wholly decomposed by the addition of distilled water. A piece of iron or zinc also causes a precipitation of a black oxyd (§ 6.), almost in the metallic state, which, according to Theuars, when dried at a low temperature, acquires the properties of a pyrophorus, inflaming spontaneously by contact with the air.

7. The *fluoric*, *boracic*, and *carbonic* acids, have no action on reguline antimony; they are capable, however, of combining with its oxyds, forming salts, the particular properties of which have not been examined.

8. The action of all the *metallic acids* on antimony, except the arsenic acid, is wholly unknown: and for this see ARSENIAT *of Antimony*.

9. The *vegetable acids* produce no other effect on metallic antimony, except blackening its surface; they dissolve, however, its oxyds without much difficulty, forming salts, a few only of which have been properly examined: these we shall proceed to particularise.

10. The *antimoniated tartar*, or *emetic tartar*, is the most important of the combinations of antimony with the vegetable acids. It was first prepared by Adrian Mynsicht, in 1631; and from that time to the present, has attracted the notice of chemists and physicians. Bergman, in his admirable essay on Emetic Tartar, was the first who gave any thing like a consistent account of the rationale, and the various chemical affinities concerned in its preparation; and the subject has of late been finally elucidated by the able and sagacious experiments of Theuars.

The tartareous acid, the acidulous tartrite of potash (or cream of tartar), and the tartrite of potash (soluble tartar, or tartarized tartar), are each capable of dissolving and combining with oxyd of antimony; an inquiry, therefore, into the chemical properties of emetic tartar, necessarily includes the consideration of the above different menstrua, and thus renders it a very complicated affair.

Pure tartareous acid and boiling water, digested on any of the oxyds of antimony, except that which is saturated with oxygen, as the diaphoretic antimony, may be made to take up one-third or one-fourth part of its own weight; and the solution, when concentrated by evaporation, and allowed to cool gradually, usually deposits a few crystalline grains, but is for the most part converted into a brownish gelatinous mass, which, at a red heat, is charred, and the antimony contained in it is partly extricated in the form of a white smoke, and partly reduced to metallic grains.

A solution of tartrite of potash, at a boiling temperature, takes up at least as much oxyd of antimony as tartareous acid is capable of dissolving; the liquor becomes slightly alkaline, and upon evaporation, yields a number of crystalline grains.

A solution of tartareous acidulum, or cream of tartar, being boiled with any of the simple oxyds, or sulphurated oxyds of antimony, dissolves a considerable quantity; and by evaporation and cooling, deposits elongated octahedral crystals of emetic tartar.

The taste of this triple salt is slightly harsh and metallic; it reddens vegetable blues; it effloresces in the air, loses its transparency, becomes of a dead white, and is then pulverulent: it requires for its solution about 40 times it weight of boiling water, and nearly twice as much at the common temperature. Sulphuric acid precipitates from it a sulphated oxyd of antimony, leaving the cream of tartar pure; the alkalies, both pure, and carbonated, decompose it in part only, a loose white oxyd being precipitated by the first, and by the second, a carbonated oxyd, which, in a short time, crystallizes in the form of divergent rays. If either tartareous acid, or tartrite of potash, is added to the solution of emetic tartar previously to pouring in the alkali, there will be no precipitate; for the tartrite of potash produced by the alkaline addition, or already existing in the fluid, immediately dissolves the antimonial oxyd; and for the same reason, a simple solution of emetic tartar cannot be wholly decomposed by any quantity of alkali; and hence probably have arisen the great seeming differences in the proportion of its constituent parts, as the salt has been analysed by means of a pure alkali, a carbonated alkali, or other re-agents. According to Theuars, the crystals of emetic tartar, from whatever antimonial oxyd they are prepared, and whatever has been the proportion of ingredients employed, contain in a given weight precisely the same quantity of antimony, of tartareous acid, of potash, and water; and even the degree of oxydation of the metal is also invariable. His method of analysing this salt, is first to ascertain its water of crystallization, by drying in a heat just not sufficient to decompose it; secondly, to dissolve the emetic tartar, and precipitate the antimony by sulphurated hydrogen; thirdly, to ascertain the tartareous acid by dropping in acetite of lead; fourthly, to determine the quantity of potash by igniting the residue, and extracting the alkali by dilute nitrous acid. By a very careful analysis, conducted in the above manner, he found 100 parts of emetic tartar to contain 38 oxyd of antimony, 34 tartareous acid, 16 potash, and 8 water, besides 4 loss. But the tartareous acidulum, which supplies both the acid and alkali to the emetic tartar, contains 57 tartareous acid, 33 potash, and about 10 water and loss; or 70 tartrite of potash, and 20 tartareous acid in excess. Hence it follows, that there is a greater excess of tartrite of potash in cream of tartar over the acid, than exists in the emetic tartar; and this excess of tartrite of potash is found in the mother water, in which the crystals of the emetic are decomposed; when, therefore, the whole is evaporated to dryness, as is often the case in the preparation of emetic tartar, there is a portion of antimoniated tartrite of potash superadded, which, no doubt, modifies its effect, and produces variations, which are unjustly changed to the emetic tartar. Another objection to evaporating the whole mass to dryness without separating the crystals, is, that the tartrite of lime which exists in a variable proportion in all cream of tartar, according to Vauquelin, is also mingled with the antimonial salt, and weakens its operation. To make, therefore, emetic tartar uniformly of the same strength, select an antimonial oxyd somewhat below the maximum of oxydation, and digest it in a hot saturated solution of cream of tartar, taking care that the oxyd shall be rather more than enough to saturate the salt (if the grey oxyd from the sulphuret of antimony is made use of, or even the common glass of antimony, as these are not already sufficiently oxydated, there will be a decomposition of water, and a small quantity of kermes will be formed); when the liquor refuses to take up any more antimony, filter and evaporate till a pellicle begins to be formed; allow the solution to cool, and select all the octahedral and tetrahedral crystals that are deposited; wash them in cold water, and again dissolve in hot water, and crystallize. For the particular formulæ of the different pharmacopœias, see § 12.

11. The only remaining antimonial salts of any consequence, are the oxalat and acetite of antimony; and we are as yet acquainted with very few particulars even concerning these. The oxalat of antimony is easily formed, and concretes into small crystalline grains; these are soluble in wine, giving it an emetic quality; and this preparation has

been ufed by fome medical men inftead of the common antimonial wine. The acetite of antimony being known before the difcovery of emetic tartar, was recommended for the fame ufes to which the former is now applied, by Angelo Sala. Neither the oxalat, nor the acetite, however, of this metal appear to be poffeffed of any fuperiority over the emetic tartar, and are now, we believe, wholly difufed.

§ 8. *Action of Neutral Salts on Antimony.*

Muriat of foda is faid to be in part, at leaft, decompofable by antimony at a red heat; but the experiments on this fubject are contradictory, and require to be performed afrefh with care and exactnefs.

Sulphat of potafh (and propably all the alkaline fulphats), is decompofed without any difficulty. This was firft fhewn by Monnet; he fufed together in a crucible two parts of fulphated potafh, and one of antimony; the metal difappeared, and he obtained a yellow, femi-vitrified mafs, intenfely cauftic, of antimoniated fulphuret of potafh; which, when wafhed with warm water, depofited, by cooling, a hydrofulphurated oxyd of antimony. The metal, therefore, in this cafe, became oxydated at the expence of the fulphuric acid; and the fulphuret of potafh refulting from this combined with the metallic oxyd, rendering it partly foluble in hot water.

Oxymuriat of potafh has a very powerful action on antimony, as it has indeed upon all the eafily combuftible metals: if equal parts of this falt, and antimony previoufly reduced to a fine powder, are mixed together, and ftruck brifkly on an anvil, or any fuitable hard body, a remarkably loud and vehement detonation takes place: if the mixture, inftead of being ftruck, is poured into fulphuric acid, or rather if the acid is poured upon the powder, a hiffing noife is produced, red fparks are emitted, and the metal is converted into an oxyd.

Nitre and *antimony*, in equal parts, or two parts of the former to one of the latter, being thrown into a red-hot crucible, detonate with a vivid flame, the acid of the nitre is decompofed, and the metal is completely oxygenated. The white mafs remaining in the crucible being pulverifed and digefted in hot water, is feparated into two parts, one foluble, and the other infoluble: the latter of thefe was formerly confidered as a pure oxyd of antimony, but Theuars has fhewn, that it contains about one-fifth of potafh, intimately united with the oxyd, which appears to act the part of an acid: it was formerly known by the name of *reguline diaphoretic antimony*, but appears, in fact, to be a kind of *antimonite of potafh*, rendered infoluble by an excefs of oxyd; the foluble part differs from the other merely in the proportion of its ingredients, being an *antimoniated potafh*, cryftallizable and decompofable, with precipitation of its oxyd, by any of the mineral acids. As, however, this is generally prepared from the fulphuret of antimony, we fhall refer the reader for further particulars to the next fection.

§ 9. *Sulphuret of Antimony—Glafs of Antimony—Kermes, &c.*

1. Sulphuret of antimony may be prepared artificially, by pulverizing a pound of reguline antimony, and mixing with it eighteen ounces of flowers of fulphur; this being put into a crucible, and brought to a low red heat, melts into an uniform mafs, of the weight of about two pounds, which, when cold, exhibits a ftriated appearance, exactly fimilar to the native grey fulphuret (§ 3.), and is poffeffed of all the fame phyfical and chemical properties; hence, for cheapnefs fake, all the preparations from the antimonial fulphuret are made with the native ore, juft feparated by fufion from the ftony and earthy matters that it is mixed with, which is known in commerce by the name of *crude antimony*, or antimony of the fhops.

2. If the fulphuret of antimony is expofed to a red heat, with accefs of air, moft of the fulphur is volatilized, and a fmall but variable proportion of the metal is carried up at the fame time: this operation being performed in a melting-pot, furmounted by a feries of aludels, the vapour as it rifes, is condenfed in the form of a light pulverulent fubftance, called *flowers of antimony*. The flowers, at the beginning of the procefs, are of a greyifh yellow colour, and confift of fulphur, with antimony, either in the metallic ftate, or at leaft very little oxydated; the next portions are orange-coloured, and thofe which rife towards the end of the operation, are almoft yellow, and confift of little elfe than pure fulphur. What remains behind at the bottom of the melting-pot is a greyifh afh-coloured oxyd, ftill holding a little fulphur: among the old chemifts it was known by the name of *grey calx of antimony*; by the moderns it is called the *grey fulphurated oxyd* of antimony. It is moft commonly prepared by flow roafting of the crude antimony in a flat difh or reverberatory furnace, and the fulphur and metal that are volatilized with it are allowed to efcape. See § 4.

3. The grey fulphurated oxyd, when urged by a fufficient degree of heat, forms a tranfparent glafs, poffeffing, according to circumftances, every fhade of colour from light yellow to the deepeft hyacinthine red; this is the *glafs of antimony*, or, according to the modern nomenclature, the *vitreous fulphurated oxyd* of antimony. In order to prepare this, any quantity of the grey oxyd is put into a crucible, and kept at a full red or low white heat till it enters into perfect fufion; foon after this has taken place, the end of a clean tobacco pipe fhould be dipped in it; and if the matter that adheres to the pipe is tranfparent, and may be drawn into a thread like common glafs, it has been heated fufficiently: the crucible is then to be removed from the fire, and its contents are to be poured on a compact flat ftone or plate of copper. When the glafs has become folid, it fhould be removed into a covered veffel, as it cracks and flies while cooling.

It fometimes happens in making the glafs of antimony, that the grey oxyd begins to melt as foon as it is red hot, and continues limpid like water, without acquiring the property of drawing into threads like glafs: at other times, on the contrary, even the long continuance of a white heat will do no more than bring it to a pafty confiftence. In the former cafe, the glafs is of an unufually deep colour; in the latter of a very light colour. This inequality arifes from a difference in the grey oxyd; if it has been too little roafted, it flows with the firft impreffion of the heat, but when more completely oxydated and defulphurated, it proves very refractory: this laft, however, may be remedied by throwing in a little crude antimony in powder, which will immediately determine its fufion and vitrification; and in this cafe there are always found at the bottom of the crucible a few grains of very pure regulus of antimony.

If the previous defulphuration has been very flight, the oxydation alfo will have proceeded but a little way; and the glafs produced, though poffeffed of a vitreous fracture, is perfectly opaque, and of a dark liver colour, hence it has obtained the name of *liver of antimony*: the fame name, however, has been given to a preparation of crude antimony and nitre, which will be mentioned prefently.

4. The action of acids upon the fulphuret of antimony is upon the whole fo fimilar to their action on the regulus, as defcribed, § 7, that it will only be neceffary to point out the circumftances in which they differ. In general, the metallic part of the fulphuret is more eafily diffolved and re-

tained by acids than the mere regulus is; and the fulphur of the compound is not at all or very little acted upon. The fulphuric and nitric acids are decompofed with confiderable energy, on pulverized fulphuret of antimony; fulphureous acid in one cafe, and nitrous gas in the other, being copioufly difengaged, the metal is oxydated, and remains intimately mixed, though no longer combined with the fulphur, very little of it being actually diffolved by thefe acids. The muriatic acid, even when cold, will decompofe a large quantity of fulphuret, during which procefs, there is a confiderable extrication of fulphurated hydrogen; if the mixture is heated, the whole of the metal enters into folution, leaving the fulphur at the bottom unaltered; a fmall portion, however, both of the fulphur and metallic oxyd is diffolved in the hydrogen, and efcapes in a gaffeous form; for Bergman obferved, by performing this experiment in a veffel with a long narrow neck, that the fulphurated hydrogen, in its paffage through, depofited a little kermes, or hydrofulphurated oxyd of antimony. The beft menftruum, however, for crude antimony, is a nitro-muriatic acid, compofed of one part nitric, and three parts muriatic acid; the metallic oxyd is entirely taken up, part of the fulphur is carried off by the hydrogen gas, another part is acidified and mixes with the other acids, and the remainder, about 26 per cent. is left at the bottom of the veffel in form of a white powder. In § 7, we have given an account of the original method of preparing the butter of antimony by fublimation of the regulus with corrofive mercurial muriat: the fame antimonial falt may be obtained by ufing fulphuret of antimony, but inftead of obtaining the mercury in a metallic ftate, it is combined with the fulphur of the antimony into a violet-coloured mafs, which, at a full red heat fublimes, and is depofited in the upper and cooler part of the veffel, in needle-form cryftals of cinnabar, hence called *cinnabar of antimony*.

5. The fixed alkalies are capable by the dry way of combing with fulphurated antimony, forming feveral important preparations. If 15 ounces of pulverized crude antimony, 12 ounces of decrepitated fea falt, and 3 ounces of tartar, are mixed together, and fufed in an earthen crucible, there will be found, on breaking the veffel when cool, that it contains two fubftances; the upper is of a lighter colour than the other, and confifts of the falt with a little fulphur; the inferior fubftance is very heavy, opaque, of a black colour, and on being broken, exhibits a fhining vitreous fracture: it has obtained the name of *medicinal regulus*, though improperly, being a fimple alkalized fulphuret of antimony, in which the metal is probably uncombined with oxygen, and nearly faturated with fulphur. A fimilar preparation to this is the *ruby of antimony*, or *magnefia opalina*, differing, however, in containing lefs fulphur, and in the metal being perhaps more oxydated. It is prepared by mixing equal parts of muriated foda (fea falt), nitre, and crude antimony, and fufing the whole in a crucible; there is a large quantity of fcoriæ in this as in the former procefs, and underneath them is a compact vitreous mafs, tranfparent in thin fhivers, and, if well made, of a deep, fomewhat fmoak-red colour, and brilliant femimetallic luftre. Neither of thefe preparations is deliquefcent or foluble in water, on account of the fmall proportion of alkaline falt that they contain. By increafing, however, the dofe of alkali, the mafs becomes foluble; thus, if to one part of fulphurated antimony we add two parts of pure dry pearlafh, we obtain by fufion a compact reddifh-brown mafs of alkaline fulphuret of antimony, and a little of the metal in its pure reguline ftate is found at the bottom of the crucible. If the whole of the antimony is required to be diffolved in the fulphurated alkali, as is the cafe in the preparation of kermes, it is requifite to add to the above ingredients about one-twentieth of their weight of fulphur. Hence it appears, that the fulphur of the crude antimony is divided between the metal and the antimony, in the compound ratio of their weights and their refpective affinities for fulphur, in confequence of which fome of the antimony is entirely defulphurated, and remains in an uncombined ftate, while the remainder being only partially defulphurated, unites into one mafs with the fulphurated alkali. If this alkaline fulphuret of antimony, coarfely powdered, is boiled in pure water, nearly the whole is held in folution as long as the liquor continues hot, fo that it may be paffed haftily through a filter; but in proportion as the liquor cools, a copious precipitation takes place, of a bulky, flocculent fubftance, whofe colour is a deep brick-red, approaching to that of the kermes infect, whence it has been called *kermes mineral*: after the depofition of kermes has ceafed, the liquor being feparated from it by a filter, is of a wine-yellow colour; and upon the addition of any acid, a ftill further precipitation is brought about, of an orange-yellow powder, which is called the *golden fulphur* of antimony. Kermes may alfo be prepared in the humid way, as was firft fhewn by Lemery in the year 1707. Since that period a multitude of proceffes have been publifhed by the French chemifts for the preparation of this fubftance; none of them, however, appear to be effential improvements of Lemery's original method; and as this has received the high fanction of the obfervant and accurate Beaumé, we fhall felect it for the ufe of our readers. Put into a clean iron pan five or fix parts of pure liquid fixed alkali, with fifteen or twenty parts of water; fet it over the fire to heat, and as foon as it has begun to boil, ftir in fome well levigated fulphuret of antimony, equal in weight to one-fixteenth of the alkali; ftir the mixture well, and when it has boiled for a minute or two, throw the whole on a filter, fo that the clear liquor may pafs through while hot; a large quantity of kermes will be depofited while it cools, which, after being feparated from the alkaline folution, is to be wafhed firft in cold, and then in hot water, till the water comes off quite infipid; the powder being then dried in the fhade by a gentle heat, and levigated and paffed through a fine fieve, is to be kept in a well-clofed phial for ufe. The alkaline liquor, when it has ceafed to depofit kermes, may be made to yield the golden fulphur, by faturating it with dilute fulphuric acid. In this procefs by the humid way, as in the other by the dry way, a partition of the fulphur takes place between the alkali and the metal, by which a portion of this laft is left undiffolved in the form of a grey powder; and this, by fimple fufion in a crucible, is reduced to a mafs of regulus. According to the French chemifts, both the kermes and golden fulphur are *hydrofulphurated oxyds of fulphuret of antimony*: and Theuars, in his experiments on the antimonial oxyds, has given the following as the refult of his analyfes of thefe two fubftances, *viz.* Kermes mineral contains,

72.760	brown oxyd of antimony,
20.298	fulphurated hydrogen,
4.156	fulphur,
97.214	
2.786	lofs.
100.000	

Golden fulphur contains,

68.3	orange oxyd of antimony,
17.877	fulphurated hydrogen,
11 to 12	fulphur.
98.177	

The theory concerning their formation is, that the alkaline antimonial fulphuret coming into contact with water, decompofes it; that the oxygen of the water combines with the fulphurated metal, while its hydrogen diffolves fome of the fulphur with which it is in contact, and unites to the fulphurated metallic oxyd in different proportions, according to the different degrees of oxydation of thefe oxyds: that when the antimony is the leaft oxydated, it unites with the greateft quantity of fulphurated hydrogen, and becomes infoluble in alkali, forming the kermes; and, on the other hand, when more oxydated, it unites with lefs fulphurated hydrogen, and remains diffolved in the alkali till precipitated thence by an acid, forming the golden fulphur. Kermes may alfo be made by paffing fulphurated hydrogen through a folution of muriat of antimony; and this among others is adduced as a proof of the kermes containing the metal in an oxydated ftate. Notwithftanding, however, the excellent experiments of Berthollet and Theuars on this fubject, many very ftrong objections may, in our opinion, be urged againft their theory: to enter into them at full length would be inconfiftent with the plan of this work, but we fhall refume the fubject when treating of the *Metallic* HYDROSULPHURETS.

6. The nature of the preparations refulting from the mutual action of nitre and fulphurated antimony, depends very much on the proportion which the nitre bears to the other ingredient. The nitrous acid is confumed in acidifying the fulphur and oxydating the antimony; and the alkaline bafe of the nitre unites with the fulphur, if any remains, with the fulphuric acid forming fulphat of potafh, and with the metallic oxyd. When the nitre confiderably exceeds the antimonial fulphuret, as in the preparation of diaphoretic antimony, the fulphur is entirely oxygenated, and partly efcapes in the form of fulphureous acid gas, while the remainder, with part of the alkali, forms fulphat and fulphite of potafh; the metal alfo is completely oxygenated at the expence of the nitre; and the oxyd hence refulting, combines with the potafh in two proportions; that portion which is united to a large quantity of alkali is rendered foluble, and the other remains infoluble. Hence when the refult of the above procefs is lixiviated with hot water, we find diffolved in the liquor, and may obtain, in a cryftalline form, fulphat and fulphite of potafh, fome undecompofed nitre, and antimonite of potafh; the undiffolved refidue, or diaphoretic antimony, confifts of the perfect oxyd of antimony combined with about a fifth of potafh.

When the nitre and crude antimony are in equal proportions, only part of the fulphur is acidified, and the metal is at a low ftate of oxydation; by the action of warm water the mafs is divided into an infoluble and foluble portion; the firft, called *crocus metallorum*, feems, like the glafs of antimony, to be merely a fulphurated oxyd; the latter confifts of kermes, of golden fulphur, and fulphat of potafh. For further particulars fee § 12.

§ 10. *Phofphuret of Antimony.*

Pelletier, in his Effays on Phofphorus, has given the three following proceffes for combining antimony with that highly inflammable fubftance. 1. To one ounce of regulus of antimony add an equal weight of glafs of phofphorus, and one dram of charcoal; pulverize the whole well together, and fufe the mixture in a covered crucible; the refult is a white metallic mafs of phofphorated antimony, very brittle, with a lamellar fracture, and nearly cubical fragments. When a little piece of it is put upon lighted charcoal, and expofed to the action of the blowpipe, it emits, at the moment of fufion, a faint green flame, and then volatilizes like pure antimony, in the form of white flowers. 2. Equal parts of regulus and glafs of phofphorus furnifh by fufion a metallic mafs, whofe fracture difplays minute facets, and in every other refpect is fimilar to No. 1. 3. A phofphuret of antimony, with the fame properties as the former, may alfo be prepared by projecting on the melted regulus fmall pieces of phofphorus. In this cafe, however, the crucible muft be removed from the fire immediately after the laft portions are thrown in, otherwife by a continuance of the heat it would be all volatilized.

The phofphurets of antimony are not applied to any ufe, and the above are all the facts which we are poffeffed of concerning them.

§ 11. *Alloys of Antimony.*

1. *Antimony with gold.* See GOLD.
2. *Antimony with platina.* See PLATINA.
3. *Antimony with filver.*

According to Lemery, one ounce of reguline antimony and three drams of cupelled filver, being fufed together in a ftrong heat, yielded an alloy of the fame weight as the original materials, and fimilar to common regulus of antimony, but more compact, and not fo brittle. Gellert (Chymie. Metallurg.) relates, that 181 grains of filver being fufed with 255 grains of reguline antimony, the alloy was found to have loft during the procefs $115\frac{1}{2}$ grains; the remainder was very brittle, and in colour fimilar to regulus of antimony: its fpecific gravity was $= 8.44$. But the fp. gr. of the filver being $= 9.1$, and that of the antimony being $= 6.7$, the fp. gr. of the alloy, fuppofing the whole lofs of weight to have been antimony, ought to be $= 7.96$. Therefore the fp. gr. of this alloy is greater than the mean of its conftituent parts. It is made no ufe of.

4. *Antimony with copper.*

Thefe two metals mixed together in nearly equal proportions, form a hard brittle alloy, of a violet colour internally, which is not very foon affected by expofure to the air. Gellert, having mixed together 314 grains of copper, fp. gr. $= 8.7$, with 464 grains of reguline antimony, fp. gr. $= 6.7$, obtained an alloy whofe fp. gr. was $= 8.02$. During the fufion there was a lofs of $43\frac{1}{2}$ grains; and putting the whole of this to the account of the antimony, the fp. gr. of the alloy ought, by calculation, to have been $= 7.49$. The fp. gr. therefore of this alloy is greater than the mean of its conftituent parts. It is made no ufe of.

5. *Antimony with iron.*

The general properties of antimony with a very fmall proportion of iron, or *martial regulus*, may be found above in § 4. Gellert having mixed by fufion $115\frac{1}{4}$ grains of iron, fp. gr. $= 8.0$ with 173 grains of reguline antimony, obtained an alloy of 63 grains lefs by weight than the materials. It was brittle, of an afh colour, and contained fpecks like ruft of iron. Its fp. gr. was $= 6.92$. Now fuppofing the lofs of weight to be placed to the account of the iron, the denfity of the alloy ought to be $= 7.05$; its fp. gr. therefore is lefs than the mean of its ingredients. This alloy was wholly unaffected by a powerful magnet, except one or two particles which appeared to be iron. It is not made any ufe of.

6. *Antimony with mercury.* See MERCURY.
7. *Antimony with tin.*

Thefe two metals being mixed together in nearly equal proportions, form a moderately hard, very brilliant, and brittle alloy, capable of receiving an exquifite polifh, and not eafily tarnifhed; it has therefore been occafionally manufactured into fpeculums for telefcopes. Gellert mixed together by fufion $231\frac{3}{4}$ grains of tin, fp. gr. $= 7.36$, with $231\frac{1}{4}$ grains of antimony; 77 grains were loft in the procefs, and the alloy was $= 6.94$ fp. gr. Suppofing the whole lofs to

be attributed to the tin, the denſity of the compound ought to be = 7.0; its ſp. gr. is therefore leſs than the mean of its ingredients.

8. *Antimony with lead.*

This is the moſt important of all the alloys of antimony, it being the material of which the common types for printing are made. In proportion as the lead exceeds the other ingredient, will be the ductility of the maſs; and the lead may be hardened, and its fuſibility unimpaired by ſo ſmall a proportion of antimony as not to injure its ductility. Gmelin found that equal parts of the two metals produced a porous brittle alloy; one part antimony, and two lead, afforded a more compact metal, but ſtill brittle; one part antimony, and three lead, gave a homogeneous metal, ductile under the hammer, and much harder than lead: one part of antimony gave to eight of lead an increaſe of fuſibility, hardneſs and colour, without materially injuring its malleability. According to Gellert, 386½ grains of lead, ſp. gr. 11.7, being fuſed with 333 grains of antimony, experienced a loſs of 101 grains. The alloy was brittle, and preſented a granular ſomewhat ſhining fracture; its ſp. gr. was = 9.17; and even if the whole loſs of weight is attributed to the antimony, the denſity by calculation ought to be = 9.12. The maſs is therefore of a greater ſp. gr. than the mean of its ingredients.

9. *Antimony with zinc.*

Equal parts of the two metals being fuſed together, formed a homogenous brittle maſs of a light aſh-colour; the loſs of weight was about one-ſixth of the whole; as however both theſe metals are very volatile, it is impoſſible to ſay with any certainty what proportion of the loſs is to be attributed to each; the ſp. gr. of the maſs was rather leſs than that of the antimony, which is the lighteſt of the two. It is not uſed.

10. *Antimony with biſmuth.*

According to Gellert, equal parts of the two metals being fuſed together, loſt $\frac{1}{25}$ of their weight, and produced an alloy of a lighter colour than biſmuth, and very brittle, diſplaying in its fracture a cubical ſtructure like that metal; the ſp. gr. of the maſs was = 8.96; whereas, ſuppoſing the $\frac{1}{25}$ of loſs to have been ſuſtained by the biſmuth, the heavieſt of the two, its denſity by calculation ought to have been only = 7.94. Not uſed.

Concerning the combination of the other metals with antimony nothing is as yet known, except merely that cobalt unites eaſily with antimony, and mangneſe with great difficulty, and very imperfectly.

§ 12. *The medicinal Virtues, and pharmaceutical Preparations of Antimony.*

This metal affords ſeveral of the moſt valuable articles of the pharmacopœia; and as it has for ſo many years engaged the attention of chemiſts and alchemiſts (of whom a large number have ever been zealous to add to the reſources of the healing art), we poſſeſs an almoſt infinite variety of antimonial preparations, all of them valuable as medicines, all enjoying many virtues in common, but a few out of the number recommending themſelves peculiarly to the medical practitioner from the uniformity of their compoſition, or from a greater tendency to one mode of operation rather than another, whereby particular indications in the cure of diſeaſes may be fulfilled.

The firſt and moſt unqueſtionable operation of antimony on the human body is that of an emetic. This operation appears to be always in direct proportion to the activity of the antimonial in every other reſpect; and it exiſts in the higheſt degree in thoſe preparations that are almoſt too virulent to be given internally with ſafety in common caſes. Antimonials excite to vomit very ſpeedily, and their action is continued on the ſtomach for a conſiderable time; hence they are of a peculiar ſervice, either where any acrid or poiſonous matter has been taken which requires to be ſpeedily and effectually removed; or in ſuch caſes as incipient fever, where, along with the clearing of the firſt paſſages, the phyſician wiſhes to prolong the mechanical action of vomiting, ſo as to induce a relaxation on the ſkin, and complete perſpiration.

The operation of antimony is alſo extended to the inteſtinal canal, and hence it proves conſiderably *purgative;* and this effect takes place, either when the doſe has been greater than neceſſary, merely to produce vomiting; or when the ſtomach has eſcaped the action of this powerful mineral. In order to ſecure the purgative, and prevent the emetic operation of antimony, it is adviſeable to unite it with ſome of the uſual aperient medicines, whoſe operation it will thus aſſiſt in a conſiderable degree.

Antimony appears to promote almoſt all the excretions, and to quicken and ſtimulate the action of the abſorbent veſſels. It is therefore eminently *diaphoretic* (or promoting perſpiration); *expectorant*, and often *diuretic*. It frequently happens that a ſingle one of the antimonial preparations may be made to produce each of theſe effects by varying the doſe, increaſing it to render it a vigorous emetic or cathartic; and diminiſhing it when the gentle and more gradual operation of a diaphoretic or expectorant is to be ſecured.

A long continued courſe of antimonials, in the mildeſt form, wherein the direct operation of this metal is ſcarcely at any one time to be detected, has been found of eſſential ſervice, both in various obſtinate cutaneous complaints, and to produce that change of conſtitution and ſuppoſed reſolution of internal obſtruction, which entitle a medicine to the (ſomewhat ambiguous) character of *alterative* and *deobſtruent.*

We ſhall now proceed to take notice of thoſe preparations of antimony which are actually in uſe, or which have acquired a certain reputation in medicine.

Antimonium preparatum (Pharm. Lond. & Edin.). This is nothing but the crude antimony or native black ſulphuret, prepared for medicinal uſe ſimply by triture to an impalpable powder, edulcoration with water, and ſubſequent drying. In this native mineral the proportion of the ſulphur to the metallic part is ſo large, as to render it almoſt entirely inert, at leaſt with regard to any ſenſible operation. It is ſometimes, however, though rarely, employed in cutaneous complaints; and formerly it was uſed in the preparation of decoctions of ſarſaparilla, guaiacum, and the other ſudorific woods; a quantity of the mineral being tied up in a looſe cloth, and ſuſpended in the veſſel in which the decoction was preparing; but as ſcarcely the minuteſt portion of the antimony could be diſſolved by this proceſs, it has properly been omitted.

The crude antimony, ſtill, however, is retained in veterinary practice; and it may be given to many animals in doſes of ſeveral ounces without any apparent operation.

It is likewiſe the material from which all the other antimonial medicines are prepared, directly or indirectly.

Antimonium vitreſactum (Pharm. Lond.), vitrum antimonii (Pharm. Edin.), Glaſs of antimony.

To prepare this, the crude antimony is roaſted on a tile or other ſhallow veſſel, with a very ſlow fire, and frequent ſtirring, till all the ſulphur is expelled which can be ſeparated in this method. What remains is a grey powder, which is to be melted in a crucible and an intenſe fire into a yellowiſh vitreſcent maſs, to be poured out on a warm copper or iron plate, and when cold reduced to a very fine

powder. This preparation is an oxyd of antimony not at its highest point of oxydation, and still retaining a small portion of sulphur, which it is impossible to separate by mere heat. When well prepared it is pretty uniform in its nature, and is a very violent medicine, operating even in small doses as a strong emetic and cathartic. It is scarcely ever employed internally, but is the basis of the emetic tartar, and the antimonial wine, in the London Pharmacopœia.

Vitrum antimonii ceratum (Pharm. Edinb.).

Take one ounce of glass of antimony in fine powder, add it to one dram of yellow wax melted in an iron vessel, heat them gently together for a quarter of an hour, with constant stirring; pour out the mass when cold, and reduce it to powder.

The glass of antimony here incorporates with the wax, and changes its colour from lemon yellow to brown in the process. The wax appears to lessen in a very great degree the activity of the antimony, so that this medicine may be given with safety, and has been much recommended in dysenteries and other bowel complaints. It is rejected from the London pharmacopœia; but retained in those of Edinburgh, Amsterdam, and some others.

A great variety of preparations have been made from the crude antimony by the intermedium of nitre. The operation of this salt on the metallic sulphuret when dephlagrated together, is first to consume the sulphur, and afterwards, if the quantity be sufficient, to oxydate the metal to the highest point. It is remarkable, that the perfect oxyd of antimony, entirely divested of sulphur, and fully saturated with oxygen, appears almost as inert as the crude sulphuret of antimony itself, whilst in the intermediate states of desulphuration, and oxydation, many very active medicines are found.

Of these the two following alone are now retained, the first with a smaller proportion of nitre, the latter fully saturated.

Crocus antimonii (Pharm. Lond. & Edin.). Crocus of antimony, also called crocus metallorum, saffran des metaux, and hepar or liver of antimony, by foreign writers.

To prepare this, take one pound of crude antimony, one pound of nitre, and one ounce of common salt, mix them accurately, and project them, a spoonful at a time, in a large crucible heated red hot; when the whole is dephlagrated, increase the fire so as to melt the mass, and pour it out. When cold it will be found to consist of two parts, the upper a whitish saline scoria, to be separated from the lower, which is the crocus of antimony. This is to be rubbed to a fine powder, and repeatedly washed with warm water, till it comes off from the powder quite insipid.

The crocus of antimony is a very violent emetic and purgative, and is seldom employed internally except in farriery. When washed it appears to have the greatest resemblance to the glass of antimony above described, and it is reserved for similar purposes, that is, as a basis for the tartar emetic and some other of the antimonial preparations.

When prepared in the large way, it would appear that it is not necessary to heat the vessel in which the mixture is fired, the heat excited by the dephlagration being sufficient to fuse the whole to the requisite degree. The whitish scoriæ here produced consist of sulphat of potash (formed by the potash of the nitre and the sulphuric acid, generated by the dephlagration of the sulphur), of the sea-salt, and probably of a portion of uncombined alkali, with some particles of the metallic sulphuret that may have escaped the action of the nitre.

Antimonium calcinatum (Pharm. Lond.), antimonium ustum cum nitro (Pharm. Edin.), calx antimonii, or diaphoretic antimony.

This is prepared, according to the London college, by projecting gradually in a hot crucible a mixture of one part of crude antimony with three parts of nitre, raising the heat after dephlagration, and continuing it for half an hour; and when cold, pulverizing and edulcorating it.

The Edinburgh college direct one part of the grey powder left after roasting crude antimony for the glass of antimony, to be dephlagrated with only an equal weight of nitre, to be heated for an hour, and afterwards reduced to powder and washed till insipid.

These two preparations are, however, essentially the same, and consist of the oxyd of antimony left after the sulphur has been entirely dissipated by the nitre, itself having been oxydated to a high degree by the same dephlagration.

As the intention of using so much nitre in the first method is to consume the whole of the sulphur as well as to oxydate the metal, it is obvious that a much less quantity of this neutral salt will be sufficient where so much of the sulphur has been driven off by roasting, as is the case in the second method. Formerly a distinction was made between the pulverized oxyd taken before, or after washing; in the first instance being termed *antimonium diaphoreticum nitratum;* and in the second, *antimonium diaphoreticum lotum;* the former, as it contained an alkaline salt, was deliquescent to a certain degree, and required to be preserved in a close vessel. It is now, however, disused, the *washed* alone being retained.

The diaphoretic antimony, owing probably to its high state of oxydation, is mild in its effects, and may be taken in large doses, without producing sickness or purging. It is naturally white and in a pulverulent state, the antimonial oxyd not being truly vitrified in the process, as it is in the preparation of the crocus of antimony, but only involved in the alkali of the nitre, from which it is separated by washing.

The several washings of this substance contain a mixture of sulphat of potash, with part of the nitre undecomposed, and the naked alkali, all holding in solution a certain quantity of antimonial oxyd.

If this compound liquor is decomposed by an acid, the metallic oxyd precipitates in the form of a white powder, which has been called the *ceruse of antimony,* or *materia perlata;* but if the liquor is merely evaporated to dryness, part of the salts crystallize together with metallic oxyd, and form the *nitrum stibiatum,* or *antimoniated nitre of Stahl.* These latter preparations are now in disuse.

Some other antimonial medicines have been prepared with different proportions of antimony and nitre, forming oxyds, all of which act in a similar manner upon the human body, but with different degrees of energy. It should seem that the middle point with regard to the proportions of antimony and nitre, that is, equal parts of each, furnishes the most active antimonial oxyd, which is the crocus; and the medicinal power seems to diminish in proportion as either of these ingredients is used in excess. Thus the completely oxydated metal, the diaphoretic antimony, is possessed of but little activity; and on the other hand, the *crocus antimonii medicinalis,* formed by dephlagrating eight parts of antimony with one of nitre, and consequently but partially desulphurated, is equally mild in its operation.

The *crocus antimonii mitior,* the proportions of which are two parts of antimony to one of nitre, is another medicine now in disuse, which appears to be more active than the last mentioned, but milder than the common crocus.

The *emeticum mite antimonii* of Boerhaave is made by employing one part of antimony to two of nitre, and is a mild and fafe medicine.

Another antimonial oxyd formerly employed in medicine, is prepared by dephlagrating the *regulus* of antimony with twice or thrice its weight of nitre, and this has alfo been termed by fome the *cerussa antimonii*.

The nitre here, having no fulphur to engage it, acts entirely on the metal, and reduces it to the ftate of a perfect oxyd, which, when wafhed, refembles in every refpect the wafhed diaphoretic antimony made with the black fulphuret and three times its weight of nitre. The regulus, however, does not require more than its own weight of nitre for this preparation; all the reft is fuperfluous.

Regulus antimonii medicinalis, vel *febrifugum Craanii*, an antimonial remedy much recommended by many of the German phyficians, and introduced in the former pharmacopœias of Edinburgh, Brandenburg, Strafburg, and others of celebrity, but now difufed.

This, which is improperly termed a regulus, is prepared by fufing together five parts of crude antimony with four of common falt and one of falt of tartar. On cooling, two fubftances are found in the crucible, an upper fcoria, containing the fea-falt, the alkali, and part of the fulphur, and the lower, a reddifh mafs compofed of the greater part of the metal, deprived of a portion of its fulphur by means of the alkali, and thus rendered more active as a medicine than the crude antimony. It is this lower reddifh mafs which is the *medicinal regulus*. The ufe of the common falt feems to be merely to affift the fufion.

Regulus antimonii. The methods of preparing the true regulus of antimony have been already mentioned. This metal ufed formerly to be caft in the form of a cup, and, owing to its flight degree of folubility in various menftrua, a powerful emetic liquor was prepared fimply by filling the cup with wine, and fuffering it to ftand for fome hours. At the fame time the cup had loft fo little of its weight that it would continue to give the fame properties to frefh portions of wine for years, or almoft centuries, without being corroded through.

In like manner the regulus caft into the form of pills would produce the emetic or purgative operation to any number of perfons in fucceffion, and hence they were called *perpetual pills*.

Thefe preparations are now, however, difcontinued.

Vinum antimonii. (*Pharm. Lond.*) Inftead of the regulus, the glafs of antimony is now employed as the bafis of this medicated wine. One ounce of this, in fine powder, is to be digefted for twelve days with frequent agitation, in a pint and a half of white Lifbon wine.

This is a very valuable antimonial, principally employed in dofes of from ten to fixty drops as a diaphoretic. The quantity of the metal taken up by the wine is extremely fmall, but is liable to vary in proportion to the acidity of this menftruum, which is one inconvenience attending its ufe.

Vinum antimonii tartarifati. (*Pharm. Lond. and Edin.*) In the former difpenfatory it is directed to be made by diffolving forty grains of emetic tartar in two ounces of boiling water, and afterwards adding eight ounces of white Lifbon wine.

In the latter, twenty-four grains of emetic tartar are fimply diffolved in a pint of the wine.

The nature and preparation of the celebrated *kermes mineralis*, or *pulvis carthufianus*, have been already explained; this is at prefent laid afide, and in its place the London and Edinburgh pharmacopœias have adopted the precipitate, formed from a liquid folution of fulphuret of antimony in cauftic alkali, by the addition of an acid, inftead of by mere cooling, as is the cafe with the kermes: this is the

Sulphur antimonii præcipitatum vel *auratum*, the golden fulphur of antimony.

To prepare it, boil for three hours two pounds of crude antimony with four pounds of the aqua kali puri (or cauftic lye), diluted with three pounds of diftilled water; ftrain it while hot through a linen cloth, and immediately add gradually dilute vitrolic acid, fufficient to precipitate the fulphurated antimony, which is of a fine golden colour. Wafh it well with warm water, and dry in a gentle heat.

The golden fulphur is of a lighter colour than the kermes, the latter being generally of a brown or brick red. Both of them confift principally of fulphur, but holding in folution a certain quantity of the metal which renders them emetic or purgative when taken in dofes of feveral grains. The golden fulphur is never ufed with a view of acting violently or by any fenfible operation, but it is employed (often combined with mercury) as a gentle alterative, with a view of keeping up a conftant perfpirable ftate of the fkin, and determining a gentle increafe to the feveral emunctories. Hence its ufe in various obftinate cutaneous complaints, and other chronical diforders.

The only folutions of antimony in acids employed in medicine are the *muriated antimony*, more commonly known by the name of *butter of antimony*, and the *antimoniated tartrite of potafh*, or the *tartar emetic*. The chemical nature of each of thefe interefting preparations has been already defcribed.

The muriated antimony is much too acrid and violent to be employed for internal purpofes. It is ufed externally as a cauftic, efpecially in farriery. The *powder of algaroth*, or the antimonial oxyd, precipitated from this falt by water alone, or by an alkaline folution, is ufed by feveral chemifts as the bafis of the emetic tartar.

Antimonium tartarifatum vel *tartarus emeticus*. (Pharm. Lond. and Edin.) To prepare this moft valuable medicine according to the London Pharmacopœia: take one pound and a half of crocus of antimony in fine powder, two pounds of cream of tartar, and two gallons of water, boil them together in a glafs veffel for a quarter of an hour, ftrain the liquor through paper, and fet it by to cool: the cryftals that form are the emetic tartar.

The Edinburgh college directs: firft, to add fome of the muriated antimony to hot water, holding falt of tartar in folution, to collect the white precipitate thus formed, and edulcorate it thoroughly: next to add nine drams of this precipitate, and two ounces and a half of cream of tartar, in fine powder, to five pints of water, and to boil the whole till the tartar is diffolved; afterwards to evaporate the liquor in a glafs veffel, till a pellicle appears on its furface, and to fet it by to cryftallize.

The emetic tartar is by much the moft valuable of all the antimonial preparations; its compofition renders it fufficiently foluble in fimple menftrua, and as it is almoft entirely infipid, and as the requifite dofe is in all cafes comparatively fmall, it may be given with great eafe to children, or wherever there would be a difficulty of getting down bulky medicines. In dofes of from one to about three grains it proves emetic, and often purges even after the ftomach has been emptied: in fmaller quantities, or mixed with various other medicines, and efpecially with thofe that correct its emetic property, it fulfills the other intentions with which antimonials are given; and with proper precautions it is always fafe, manageable, and highly to be depended on.

When prepared in the fame way, it is generally very uniform in its nature, but it is liable to fome variation, when different antimonial oxyds are ufed; an inconvenience it would be of great importance to prevent.

The laft of the antimonial medicines that we fhall mention, is the *pulvis antimonialis (Pharm. Lond.)*, or the *antimonium calcareo-phofphoratum. (Pharm. Edin.)*

To prepare it. Take equal parts of crude antimony and hartfhorn fhavings, mix them together, and throw them into a wide iron pan, heated fully red, and ftir them conftantly till they acquire an afh-colour; then take them out, reduce them to powder, fill a coated crucible with it, and lute over the top another crucible, inverted, and with a fmall hole at the bottom, to ferve as a cover: then raife the fire gradually to a full white heat, and keep it in this ftate for two hours; when cold, take out the contents, reduce them to a moft fubtile powder, and it is the pulvis antimonialis.

This preparation is intended as a fubftitute for the JAMES's POWDER, one of the moft celebrated empiric medicines in this or any other country, the value of which has long been eftablifhed by the moft unequivocal teftimony. We fhall refer the reader to this article for an account of the ingenious analyfis made by Dr. Pearfon of this powder, and publifhed in the Philofophical Tranfactions, whereby it is proved to be a mixture of an oxyd of antimony with the earth of bones, or calcareous phofphat; and hence the pulvis antimonialis has been employed as a fubftitute.

This preparation is given in dofes of one to five or fix grains, or even more, and is employed peculiarly in removing general fever, by means of perfpiration. It is never intentionally given in fuch large dofes as to prove emetic; but it is generally fuppofed, that the genuine James's Powder may be taken in larger dofes than the antimonial powder, without exciting ficknefs.

We may add, that Mr. Chenevix, (in the Philofophical Tranfactions for 1801) has given the following ingenious method of preparing this medicine in the moift way, which removes every caufe of variation which may take place whenever the oxyd of a metal fo volatile as antimony is in certain ftates, is fubjected to intenfe and long-continued heat. The following is the fimple procefs: "Diffolve together, or feparately, in the leaft poffible portion of muriatic acid, equal parts of the white oxyd of antimony, formerly called algaroth powder (made by dropping the butter of antimony into water), and of phofphat of lime; pour this folution gradually into diftilled water, previoufly alkalized by a fufficient quantity of cauftic ammonia: a white and abundant precipitate will take place, which, well wafhed and dried, is the propofed fubftitute for James's Powder."

In this procefs, the antimony and the phofphat of lime are precipitated from their folution in muriatic acid at the fame inftant, the former by means both of the ammonia and the water in which it is diffolved, and the latter merely by this alkali. Hence, the inventor gives the ufeful caution to pour the mixed muriatic folutions *into the alkaline liquor*, and not to add the latter to the former; in order that the precipitation of the antimony and the phofphate of lime may be confentaneous, and therefore in uniform proportion from firft to laft. The muriatic acid fimply diffolves phofphat of lime, and does not decompofe it, and therefore it is feparated unchanged from its folution by the ammonia. If it be wifhed to prepare this powder with a ftronger dofe of antimony, it is only requifite to increafe the proportion of muriated antimony to the muriated calcareous phofphat, before the precipitation is made.

We fhall only add to this fhort review of the various antimonial preparations ufed in pharmacy, that feveral other preparations, flightly varying from thofe which we have mentioned, have been at times recommended by feveral eminent men, and have had a certain vogue; but it does not appear that any thing further can be expected from any other change in the preparation of antimonial medicines; and thofe which we already poffefs, form fome of the moft valuable articles of the Materia Medica.

§ 13. *Ufes of Antimony.*

The ufes of antimony are not very numerous; it is of high value in medicine, and is employed, in combination with other metals, in the manufacture of printers' types, and fpecula for telefcopes. Its oxyds are ufed in colouring glafs; the fulphuret is employed in fcorifying copper and other metals which are found mixed with gold; hence it was called by the alchemifts *balneum regis*, or *balneum folis*.

The native antimony, at firft, was of fervice only in the compofition of paint. Scripture defcribes it to us as a fort of paint, with which the women blacken their eye-brows. Jezebel underftanding that Jehu was to enter Samaria, painted her eyes with antimony, or, according to the Hebrew, "put her eyes in antimony."

At this day the women of Syria, Arabia, and Babylonia, anoint and blacken themfelves about the eyes; and both men and women put black upon their eyes in the defert, to preferve them from the heat of the fun, and the piercing of its rays. M. D'Arvieux tells us, that the Arabian women border their eyes with a black colour made of *tuty*, which the Arabians call *rebel.* They draw a line of this kind of blacking without the corner of their eyes, to make them appear larger. Ifaiah, in his enumeration of the feveral ornaments belonging to the daughters of Sion, has not forgot the needles which they made ufe of in painting their eyes and eye-lids: nor has this practice efcaped the lafh of Juvenal.

> "Ille fupercilium madida fuligine tinctum
> Obliqua producit acu, pingitque trementes
> Attollens oculos."

Ezekiel, defcribing the irregularities of the Jewifh nation, under the idea of a debauched woman, fays, that fhe bathed and perfumed herfelf, and that fhe anointed her eyes with antimony. Job fhews fufficiently how much antimony was in efteem, by calling one of his daughters a veffel of antimony, or a box to put paint in, *cornu ftibii.* Tertullian and St. Cyprian have declaimed very warmly againft this cuftom of painting the eyes and eye-brows.

Arabic Gum

ARABIC *gum, gum Senegal, gummi Arabicum, Acaciæ veræ succus.* This valuable article of commerce is a very pure concrete mucilage, which exudes from the *Mimosa Nilotica,* or *Acacia Vera,* a tree that grows abundantly on the sandy soil of Egypt and Arabia, on the banks of the rivers Senegal and Niger, near the Cape of Good Hope, and in several other parts of Africa. The fruit of the same tree also yields another mucilaginous juice, but at the same time considerably astringent, and of a brown colour, which has been already mentioned under the article ACACIA.

The purest gum arabic is brought in caravans to Cairo by the Arabs of the country around mount Tor and Sinai, who bring it from this distance on the backs of camels, sewn up in bags of skin, and often adulterated with sand and other matters.

The settlement at Senegal is another great mart for this commodity; and the gum, which bears the name of this place, is generally in larger masses, and of a yellowish or amber colour, but it does not sensibly differ from the Egyptian gum in any of its properties.

This mucilage exudes spontaneously in a liquid state from the trunk and boughs of the tree, and hardens by contact with the air and the heat of the sun. It begins to flow about December, immediately after the rainy season, near the flowering time of the tree. Afterwards as the weather becomes hotter, incisions are made through the bark, to assist the transudation of the juice.

The best gum arabic is brought over in oblong or roundish lumps seldom bigger than a walnut, nearly transparent, white, or of a pale yellow, wrinkled, and of a shining fracture. It is so brittle as easily to be reduced to a fine powder. It is also perfectly insipid and inodorous, dissolving in the mouth into a clammy liquid.

As the gum arabic is the most perfect specimen of a *gum* MUCILAGE, all the properties which we shall now mention to belong to it, may be considered as descriptive of this whole class of chemical substances.

The habitudes of this gum with water affords one of its most striking characters. When added to water, either cold or hot, and not less than twice its weight, it dissolves slowly, and converts the whole into a very slimy viscid liquor. Heat does not coagulate this solution; a gentle evaporation will expel the water and leave the gum as solid and brittle as before, equally resoluble in water, and unaltered in any of its properties. In this respect it differs in a striking manner from most other vegetable substances.

It is entirely insoluble in ardent spirit and in oils; alcohol indeed coagulates the watery solution, by uniting with the water, and thus precipitating the gum.

Gum mucilage is but little inflammable, when put into the fire it swells and grows puffy, and soon is reduced into a voluminous coal. Distilled *per se* in a retort, it first yields a limpid water, then an acid (which was at one time supposed to be peculiar, and was termed the PYRO-MUCOUS), and afterwards a thick empyreumatic oil, and a little volatile alkali, like all the distillations of vegetable matter.

The pure gum mucilages, when dry and solid, will remain unchanged for any length of time: the watery solution is likewise the least alterable of all the vegetable liquids; but by long keeping it becomes sour and grows mouldy on its surface, if it is prevented from drying up by the evaporation of its water.

When nitric acid is distilled off gum arabic, or any other of the gum mucilages, a peculiar acid is formed, which appears as a white powder of difficult solution, and has been termed the MUCOUS *acid.* It is the same with the SACCHO-LACTIC *acid* of Scheele.

The specific gravity of the solid mucilages, according to Fourcroy, is from 1.3 to 1.48.

The gum which exudes in considerable abundance in our own climates from the apricot, plum and cherry trees, bears the strongest resemblance to the gum arabic in all its properties, only it is generally of a yellower colour, not so brittle, and forms a mucilage of somewhat less tenacity.

Gum arabic is employed for a number of valuable purposes both in the arts and in medicine. It may be used either to suspend in water a number of substances which could not otherwise be kept equally diffused in this liquid, or as a means of glueing together a variety of articles of light work; and as a clean colourless cement perfectly easy of application, and which may be prepared in a few minutes, it is peculiarly valuable. Gum Senegal is used in very large quantities by the calico printers, to mix the colours and the mordants in block printing; gum arabic forms the basis of crayons, and the cakes of water colours, and of several liquid colours, of which common writing ink is a familiar example.

All the gum mucilages are considerably nutritious; in the countries where the gum arabic and senegal grow native, it forms an important article of food, either by itself, or mixed with milk, rice, &c. Hasselquist relates an instance of the travellers of a large caravan, who had consumed

all their provisions in the middle of their journey, preserving themselves from famine by the gum arabic which they were bringing as merchandise.

In medicine, this gum is employed, either by itself, or as a vehicle for other substances. Taken internally, it has been supposed to be incrassating and obtunding; qualities, however, which probably have little foundation in fact and real observation. As it is simply mucilaginous, it will certainly in some degree protect the parts with which it comes in contact from the effect of any acrid and stimulating substances; and thus it is of use in quieting the tickling cough which arises from any acrimony in the fauces, and in some cases it is of material service in diarrhœa and dysentery. It is given either in powder, or dissolved in water, almond milk, &c.; and one ounce of the gum is sufficient to give a considerable thickness to a pint of liquid, without making it too slimy to drink with pleasure.

In pharmacy, gum arabic possesses the valuable property of rendering miscible with water the balsams, resins, fixed oils, and similar substances, whereby they may be very commodiously taken in a liquid form. One part of gum arabic previously softened with water (or an equivalent quantity of the mucilage), will thus render four parts of balsam or oil soluble in any watery liquid, and will form an uniform emulsion. Even mercury may be thus suspended in water by being previously rubbed for a considerable time with gum arabic, which preparation is called, from the inventor, *Plenk's solution*. The corrosive acids, when taken internally, are best diluted with a solution of this gum.

The pharmaceutical preparations, in which gum arabic enters as a principal ingredient, are the *Mucilago gummi Arabici*, a simple solution of one part of the gum in two parts of boiling water; the *Emulsio Arabica Ph. Edin.* which is gum arabic dissolved in almond milk; the *Trochisci Arabici*, with gum arabic, starch and sugar; and the *Pulvis tragacanthæ compositus Ph. Lond.* a powder made of tragacanth, gum arabic, starch, and sugar. *Murray Appar. Med. Fourcroy*, &c

Arkwright

ARKWRIGHT, Sir Richard, in *Biography*, an eminent manufacturer, advanced himſelf, by his mechanical inventions for carding and ſpinning cotton, from the humble ſtation of a country barber to an immenſe fortune and an honorary title. For performing theſe operations of carding and ſpinning by means of machinery, it was required either that the uſual manœuvre of the carder ſhould be effected with ſquare cards, or that cylinders, covered with a kind of metallic bruſh work, ſhould be made to revolve in contact with each other, either to card or to ſtrip, according as the reſpective velocities, directions, and inclinations of their wires might be adjuſted. With regard to ſpinning, it would be indiſpenſably neceſſary, not only that the raw material ſhould be very nicely prepared, but alſo that it ſhould be regularly drawn out by certain parts repreſenting the fingers and thumbs of the ſpinner. The contrivance for this purpoſe conſiſted of a certain number of pairs of cylinders, each pair revolving in contact with each other. Suppoſe then that a looſe thread or ſlightly twiſted carding of cotton were made to paſs between one pair of cylinders, properly adapted with a facing for holding it, and that it proceeded from thence to another pair, whoſe ſurfaces revolved with a much greater velocity; it is evident, that this quicker revolution would draw out the cotton, and render it thinner and longer when it came to be delivered at the other ſide. This is the operation which the ſpinner performs with his finger and thumb; and if the cotton be delivered to a ſpinning apparatus, it will be converted into thread. Sir R. Arkwright contrived to make theſe rotatory carding and ſpinning engines to move by horſe, by water, and by ſteam; and thus, by the ſaving of labour, and with the advantage of a patent monopoly, he was rendered one of the moſt opulent of our manufacturers.

After he had quitted his original buſineſs, in the year 1767, he came to Warrington, where he projected a mechanical contrivance for a kind of perpetual motion. A clock-maker of this town, whoſe name was John Kay, diſſuaded him from it, and ſuggeſted that much money might be gained by an engine for ſpinning cotton, which Kay promiſed to deſcribe. Arkwright at firſt objected, but afterwards aſked Kay, if this engine might be made at a ſmall expence? Kay had been employed in making a cotton ſpinning engine; and in the trial for ſetting aſide Arkwright's patent, it was proved that he had invented ſuch an engine, but he had not brought it to perfection. Kay and Arkwright applied to Peter Atherton, eſq. of Liverpool, for aſſiſtance in the conſtruction of ſuch an engine, who, diſcouraged by the mean appearance of the latter, declined undertaking it; though he ſoon after agreed to lend Kay a ſmith and watch-tool maker to prepare the heavier part of the engine, whilſt Kay himſelf undertook to make the clock-maker's part of it, and to inſtruct the workmen. In this way Arkwright's firſt engine, for which he afterwards took out a patent, was made. Mr. Arkwright ſoon after connected himſelf in partnerſhip with Mr. Smalley of Preſton in Lancaſhire; but their property failing, they went to Nottingham, and there, by the aſſiſtance of wealthy individuals, erected a conſiderable cotton mill turned by horſes. A perſon of the name of Hayes had alſo employed himſelf in making cylindrical carding engines. Upon the whole, without minutely detailing further particulars, it appears that the cotton ſpinning was no new attempt when Mr. Arkwright embarked in it; but many difficulties occurred in bringing it to perfection. In the hands of Mr. Arkwright, the carding and ſpinning of cotton became a great national manufacture. According to his ſtatement, it appears that the advancement of it during a period of five years, coſt him and thoſe that were concerned with him 12,000*l.* before they derived from it any profit; and it muſt be allowed, that he alone ſeems to have had ſufficient perſeverance, activity, and ſkill to perfect a ſcheme, in the proſecution of which many others had failed, and to render it valuable to himſelf and the public. The merits of ſir R. Arkwright may be ſummed up with obſerving, "that the object in which he was engaged is of the higheſt public value; that though his family were enriched, the benefits which have accrued to the nation, have been incalculably greater; and that upon the whole, he is entitled to the reſpect and admiration of the world." He was knighted by his preſent majeſty on the 22d of December 1786, on occaſion of preſenting an addreſs from the high ſheriff and hundred of Wirkſworth; and died at his works at Crumford in Derbyſhire, Auguſt 3d, 1792. Gen. Biog.

Arsenic

ARSENIC, *Arſenique*, Fr. *Arſenik*, Germ. *Arſenicum*, Lat. Αρρενικον, Αρσενικον, Theoph. & Dioſcorid.

Arſenic is a brittle acidifiable metal, of a bluiſh white colour, eaſily tarniſhing by expoſure to the air: it does not melt, but volatilizes by a gentle heat, exhaling copious white fumes, with a peculiar alliaceous or garlic ſmell; it is ſoluble in nitro-muriatic acid, and is precipitable in the form of a light orange-coloured powder by ſulphuret of ammonia, or of a green colour by ammoniated copper.

§ 1. *Ores of Arſenic.*

Beſides the ores of arſenic properly ſo called, this metal is found in combination with ſilver, copper, iron, lead, cobalt, antimony, and lime, all of which will be treated of in their proper places: at preſent we ſhall confine ourſelves to thoſe ſubſtances which, by the common conſent of mineralogiſts, are arranged as ores of arſenic.

Sp. I. Native Arſenic. *Arſenic teſtacée*, Born. *Arſenic natif*, Hauy and Brochant. *Gediegener arſenick*, Emmerling, &c. *Arſenicum nativum*, Werner. *Arſenicum nigrum*, *Cobaltum teſtaceum*, *Fliegenſtein*, *Scherbenkobelt*, &c. of the older writers.

Its colour when newly broken is a very light lead-grey, often paſſing into tin white; but the ſurface, by a ſhort expoſure to the air, becomes yellow, then blackiſh grey, and finally almoſt black.

It is found generally in maſs, more rarely diſſeminated; in kidney-ſhaped or cluſtered maſſes, or in plates, or carious, branched, bearing impreſſions, &c. Externally it is rough or granular, with little or no luſtre; internally it is little ſhining, with a metallic luſtre.

Its fracture is ſometimes fine-grained, uneven, or curved lamellar; more rarely radiated or bundled. It flies when broken into indeterminate blunt-edged fragments, ſometimes in the form of plates. It is alſo frequently compoſed of diſtinct concretions, either teſtaceous, concentric, or kidney-ſhaped.

It acquires a poliſh by friction, and emits an alliaceous odour; is half-hard and brittle. It rings when ſtruck by a hard body.

Sp. gr. according to Briſſon 5.724 . . . 5.763; according to Kirwan 5.67.

Before the blow-pipe native arſenic fuſes without difficulty, giving out a copious, white, alliaceous fume; by an increaſe of heat it takes fire, burns with a bluiſh flame, and is wholly diſſipated. It depoſits on the charcoal, or any cold ſubſtance that is preſented to it, a white powder, which is oxyd of arſenic.

Native arſenic is not, however, in a ſtate of abſolute purity; it always contains a ſmall and variable proportion of iron; beſides occaſionally a little gold or ſilver.

This mineral is found at Worlich and Joachimsthal, in Bohemia; at Freyberg, Annaberg, Schneeberg, Marienberg, and Johangeorgenstadt, in Saxony; at Andreasberg, in the Hartz; at Geisberg and Seltspach in Carinthia; at Nagyag in Transilvania; and St. Marie-aux-mines in France. It occurs only in the veins of primitive mountains: the substances that accompany it are red silver, realgar, galena, native silver, specular cobalt, kupfernikkel, spathose iron, fahlerz, pyrites, quartz, heavy spar, calcareous and fluor spars.

Sp. II. Marcasite or Mispickel. *Arsenical pyrites* Kirw. *Fer arsenical* Hauy. *Arsenik kies* Germ. *Arsenicum mineralizatum pyritaceum* Werner.

Of this there are two varieties.

Var. 1. Common Marcasite. *Gemeiner arsenik kies* Germ. Its colour where recently fractured is silvery white, but in general its surface is yellowish, greyish, or bluish, sometimes iridescent. It occurs in mass, disseminated, investing, or crystallized. The primitive form of its crystals is a strait rhomboidal prism, the angles of whose base are 103° 20′ and 76° 40′: the other varieties that have been ascertained are, the rhomboidal prism with dihedral summits (Fer arsen. ditetraedre of Hauy), and the same prism with tetrahedral summits (F. ar. quadrioctonal of Hauy). The lateral faces also sometimes cylindrical, either concave or convex. The faces composing the sides of the prisms are always smooth and shining; those of the summits are crossed by striæ. Internally the marcasite is shining, with a metallic lustre. Its fracture is uneven, coarse, or finely granular; presenting occasionally columnar or granular distinct concretions. When broken it flies into indeterminate sharp-edged fragments. It is hard, generally giving fire with steel, and diffusing an alliaceous odour; is brittle, but difficult to break.

Sp. gr. according to Gellert 5.75; according to Hauy 6.52.

When exposed to the flame of the blow-pipe on charcoal, this mineral gives out a copious arsenical fume, and melts into a globule of brittle iron. Its analysis has not yet been made with any accuracy, and probably the amorphous kind at least, on account of the variable proportion of its ingredients, is incapable of affording an exact result. The constituent parts of pure mispickel appear to be only arsenic and iron, both of them in the metallic state: but it is often intimately mixed with iron pyrites, and hence affords an uncertain quantity of sulphur: two specimens analysed by Vauquelin, yielded respectively 38.8 and 4. per cent. of arsenic, which seems to shew that mispickel and pyrites, though, when pure and crystallized, sufficiently distinct from each other, are so intimately blended by nature, as to pass by insensible gradations from one to the other extreme of the series. In several of these compounds, however, minute inspection has discovered small separate cubes of pyrites; and these intermediate varieties are rather to be considered as simple mixtures than chemical compounds.

The two substances with which marcasite is liable to be confounded, are arsenical cobalt and pyrites. It differs from the first in being harder, in having a yellowish white tint, while the colour of the other is reddish white, and in the form of its crystals: it is distinguished from the latter by giving out when struck an arsenical, instead of a merely sulphureous odour, by the lighter yellow of its colour, and by its crystalline forms.

Marcasite is found in Bohemia, in Saxony, in Silesia, in Cornwall, and various other places, either in veins, or disseminated through primitive mountains. The substances by which it is accompanied, are generally tin-stone and galena; more rarely black blende, spathose iron, copper pyrites, quarz, fluor and calcareous spars. At Reichenbach in Silesia, it is found in serpentine rock.

Marcasite appears to be made little or no use of: the more brilliant specimens are occasionally cut and polished, and made into buttons, and other small articles; this is particularly the case with some found near Dublin, and called Irish diamonds.

Var. 2. Argentiferous marcasite. *Weisserz* Werner.

Its colour is similar to that of the preceding variety, but when exposed to the air it tarnishes to a deeper yellow. It is rarely found in mass, being generally disseminated or crystallized in minute acicular four-sided prisms. Externally it is shining, internally little shining, with a metallic lustre. Its fracture is fine-grained, uneven, with granular distinct concretions.

Its other external and chemical characters correspond with those of the preceding variety, from which it differs only in a variable proportion of silver, from 1 to 10 per cent.; and for which it is often worked.

It is found at Freyberg and Braunsdorf in Saxony; and is usually accompanied with common marcasite, red silver, galena, copper pyrites, &c.

For the affinities of this mineral with arsenical silver, see Silver, *Ores of*.

Sp. III. Sulphurated arsenic. *Rauschgelb* Germ. *Arsenic sulfuré* Hauy. *Arsenicum mineralizat. risigallum* Werner.

This species is divided into two varieties, the red and yellow.

Var. 1. Realgar. *Rothes rauschgelb* Emmerling. *Arsen. min. risigall. rubrum* Werner *Arsenic sulfuré rouge* Hauy. *Rubine d'arsenic, Sandarac, Rubinschwefel*, &c.

Its colour is a bright Aurora red, passing on one hand to scarlet-red, and on the other to yellow-orange. It is rarely found in mass, more frequently disseminated or investing, and very frequenely crystallized. The primitive form of its crystals is a long octahedron, with scalene triangular faces exactly the same as sulphur. The two pyramids of the octahedron are sometimes intercepted by a quadrilateral prism (see *Crystallographical Plates*, *fig.* 94.), forming the variety A. s. r. émoussé of Hauy: other varieties are derived from bevilling and truncating the angles of the intervening prism; and a further variety (*fig.* 95.) A. s. r. surcomposé of Hauy, is produced by the truncature of all the solid angles of the terminating pyramids. The crystals are for the most part small, and not easy to determine. Their surface and interior are shining or much-shining, with a vitreous lustre. The fracture is uneven granular, passing into minute conchoidal: the fragments are indeterminate, blunt-edged. It is commonly translucid, occasionally semi-transparent or opaque. The colour of its streak is orange-yellow. It is very tender, somewhat brittle, and easily broken by the nail. Sp. gr. according to Bergman 3.22. Brisson 3.33. It is idio-electric acquiring the resinous electricity by friction.

Before the blowpipe it melts easily, burns with a blue flame, and a sulphureous arsenical odour, and is for the most part volatilized. Nitrous acid in a short time deprives it of its colour. It has never been accurately analysed, but consists principally of arsenic and sulphur.

Realgar occurs native in the vicinity of Ætna and other volcanoes, and also in the primitive mountains of Germany, Hungary, and Swisserland. The substances that are found most frequently to accompany it are native arsenic, red silver, and galena.

The substances that it resembles are red silver and chromated lead; it may, however, be distinguished from the first by the following properties: the powder of the silver ore is red, that of the realgar orange-yellow; the sp. gr. of the

filver ore is the greateft, in the proportion of about 5 to 3; befides which, it does not become electric by friction, nor does it flame or volatilize by the blowpipe. Chromated lead is more than twice as heavy as realgar, and exhibits the fame differences with regard to electricity and habitude before the blowpipe as red filver.

Native realgar is made no ufe of; for the purpofes to which the artificial is applied, fee § 12. of this article.

Var. 2. Orpiment. *Gelbes raufchgelb*, Emmerling. *Arfen. min. rifigal. flavum*, Werner. *Arfen. fulf. jaune*, Hauy. *Auripigmentum*, Lat.

Its ufual colour is a beautiful lemon-yellow, paffing on one fide into fulphur-yellow, gold-yellow, or honey-yellow, and on the other into aurora-red. It is found diffeminated, and in mafs. It is internally fhining, or very fhining, with a bright waxy luftre, fometimes paffing into the metallic. Its fracture is ftraight or curved foliated. In mafs it is rarely more than tranflucid at the edges, but in thin plates is femi-tranfparent. Its ftreak is of the fame colour as the mineral itfelf, only a little lighter. It is very tender, foft to the touch; when in plates is flexible though not elaftic. Sp. gr. 3.45. It is idio-electric, and in its chemical characters, correfponds with the preceding variety. It confifts of fulphur and arfenic, but the proportions are not afcertained with accuracy.

Orpiment is found in the Bannat in Natolia and Servia, at Nagyag in Tranfilvania, Felfobanya in Hungary, &c.

It appears to be a mineral of late formation, being always found in ftratiform mountains. It is, for the moft part, accompanied by clay, quartz, &c. &c. fometimes by realgar.

The cryftalline forms that are ufually attributed to this mineral are, upon the authority of Hauy, referred to the preceding variety.

Sp. IV. Native oxyd of Arfenic. *Arfenic oxydé natif*, Fr. *Naturlicher arfenik kalk*, Germ. *Arfenicum ochraceum album*, Werner.

Its colour is fnow-white or yellowifh, reddifh, or greenifh-white; it is found alfo of a clear fmoke grey. Its common form is that of a fuperficial earthy friable cruft on the furface of other minerals: more rarely it occurs in an indurated ftate, either ftalactitic, cluftered, or cryftallized. The cryftals are always extremely minute, fometimes capillary, bundled, interlaced, or diverging, fometimes in octahedrons, fometimes in quadrilateral tables. When cryftallized it appears to be tranflucid, but in the earthy ftate it is always opaque. It is very tender, often friable, brittle; has a very fharp difagreeable tafte. Sp. gr. 3.7.

Before the blowpipe it gives out a white fmoke, and the ufual arfenical odour; the grey coloured, as being little oxydated, burns with a bluifh flame: after a time, but not fo quickly as native arfenic, it is almoft wholly volatilized. It is foluble in fifteen times its weight of boiling water: and appears to be an oxyd of arfenic nearly pure with a variable proportion of oxygen. The only fubftance with which it is liable to be confounded, is the Pharmacolite, or native arfeniat of lime: this latter however is infoluble in water, and leaves a confiderable refidue when expofed to the blowpipe.

The native oxyd of arfenic is a mineral of very rare occurrence; it is found at Joachimfthal in Bohemia, in Saxony, Heffe, Tranfilvania, and Hungary, in the vicinity of native arfenic, and in certain cobalt mines.

Lenz, verfuch der Mineralien, vol. ii. p. 229.. Kirwan's Mineralogy, vol. ii. p. 254. Hauy, Traité de Mineral. vol. iv. p. 220. Weidenmann, Handbuch, &c. p. 965. Brochant, Traité de Mineral. vol. ii. p. 435.

§ 2. *Affay and Analyfis of Arfenical Ores.*

Arfenic is a metal in itfelf of fo little value, and fo noxious to other metals by its obftinate adherence to them, rendering them brittle, and debafing their colour, that in all works in the great, and even in almoft all docimaftical affays, every method has been reforted to in order to drive off the arfenic, and its proportion to the whole mafs has only been vaguely eftimated by the lofs of weight experienced during the procefs. The methods employed by Bergman, and the reft of his contemporaries, for afcertaining the quantity of arfenic in any of its ores, are extremely imperfect; even the accurate Klaproth confeffes the imperfections of his mode, and till the publication of Mr. Chenevix's Analyfis of the Arfeniates of Copper and Iron, chemiftry had attained no certainty in the refolution of this important problem. We fhall firft mention the advantages and defects of the methods recommended by Bergman, Kirwan, Klaproth, &c. and then proceed to the more accurate ones of Chenevix.

For the decompofition either of the *native arfenic* or *marcafite*, Bergman propofes to treat the pulverized ore with four times its weight of nitro-muriatic acid, formed of one part nitrous and one and a half or two parts muriatic acid. By this menftruum the filver will be converted into muriated filver, and will, together with the filex, remain undiffolved, and the arfenic and iron will continue in folution. The filtered liquor is to be evaporated to one-fourth of its bulk, and poured into water; the arfenic will thus be precipitated, and the iron may then be thrown down from the filtered liquor by ammonia, &c. Another way of proceeding is to boil the ore with dilute nitrous acid, in order to take up the filver, copper, &c., while the arfenic will remain behind in form of a powder, and may afterwards be taken up by nitro-muriatic acid, and precipitated from its folution by water.

To thefe methods, however, it may be objected, 1ft, That the precipitation of arfenic from its folution in nitro-muriatic acid by water, is denied by fome chemifts; and even if the fact of precipitation be allowed, ftill it is certain that fome of the arfenic will remain in folution. 2dly, Antimony, which is often mingled with arfenical ores, will alfo be thrown down by this procefs. 3dly, The Ammonia added to the remaining liquor, befides precipitating the iron, &c. will, by deftroying the excefs of the nitro muriatic acid, allow the arfénic acid to combine with the oxyd of iron, and thus induce an error in the proportion of this laft metal. 4thly, It appears from the uniform experience of Klaproth, and other eminent chemifts, that arfenic is abundantly foluble in nitrous acid, and that the filver precipitated from fuch a folution, even by muriat of foda, contains a little arfenic; and whichever of the alkalies was afterwards ufed for throwing down the copper, &c. the neceffary neutralization of the nitrous acid would afford an opportunity for the arfenic acid to combine with the oxyd of copper.

The *native oxyd of arfenic* is propofed by Kirwan to be diffolved in boiling water, and of courfe its proportion is to be eftimated by the lofs of weight fuftained by the quantity of ore thus treated. But (befides other objections) the dark-coloured varieties of this ore are probably not fufficiently removed from the metallic ftate, to be thus foluble. In order to decompofe *realgar* or *orpiment*, Bergman directs long-continued ebullition with muriatic acid, adding, if neceffary, a little nitrous, till the infoluble refidue becomes grey. The infoluble powder is the fulphur, and the arfenical folution is to be decompofed as before mentioned by water. In this procefs, however, the fulphur will ftill retain fome arfenic; and a little of the fulphur will be oxygenated, and converted into fulphuric acid. Mr. Kirwan

recommends to precipitate the arfenic from the muriatic acid by zinc; but, according to Mr. Chenevix, the precipitate is not pure metallic arfenic, but a mixture of this with arfeniat of zinc.

The analyfes in the dry way of the arfenical ores, are ftill lefs fatisfactory than thofe in the humid way above recited. If fublimation in clofe veffels is had recourfe to, a very intenfe and long-continued heat will be infufficient to volatilize the whole of the arfenic; the fulphur will alfo rife at the fame time and produce orpiment. Roafting in a muffle, provided the ore is mixed with powdered charcoal, is more effectual; but in this cafe, not only the arfenic, but the fulphur and antimony, if there happens to be any in the ore, will fly off, and the relative properties of thefe muft be eftimated by mere guefs.

Klaproth's method of treating the unfulphurated ores of arfenic, may be deduced from his analyfis of the arfenical filver ore which confifts of iron, arfenic, filver, and antimony. He firft digefts the ore with moderately ftrong nitric acid, which takes up the arfenic and the greateft part of the iron and filver: the addition of muriat of foda, throws down the filver in the ftate of muriat combined with a few atoms of arfenic; and afterwards the arfeniat of iron is thrown down by potafh; this precipitate being dried and weighed, is afterwards roafted with charcoal feveral times, till it ceafes to give out arfenical fumes, and is attractable by the magnet: from the lofs of weight fuftained by the iron, the quantity of arfenic is then eftimated. This however, as Mr. Klaproth himfelf obferves, is a very imperfect method. Another way practifed by him in the analyfis of the arfenical cobalt is, to digeft the ore in nitric acid, which oxydates the arfenic and takes up the greater part of it, leaving the refidual arfenic foluble in water. The nitrous folution is then evaporated as long as it continues to depofit oxyd of arfenic, and the oxyd of cobalt afterwards feparated by potafh from the nitrous acid, is prefumed to be pure becaufe it affords a fympathetic ink with muriatic acid. From this humid analyfis the cobalt ore is ftated by Klaproth to contain 54.5 cobalt, 45 oxyd of arfenic and ½ fulphur: a fpecimen however, of the fame ore treated in the dry way, afforded only 44 cobalt; there was therefore required to make up the 100, ½ fulphur, and 55.5 reguline arfenic. Hence it is evident, that little dependence is to be placed on the eftimation of the quantity of arfenic from the oxyd precipitated by evaporation of the nitrous folution.

A more certain mode of afcertaining the proportion of arfenic, is furnifhed by Mr. Chenevix. Let the ore, previoufly reduced to extremely fine powder, be digefted in nitric acid fufficient to acidify and take up the whole of the arfenic; pour off the clear liquor, and boil on the refidue fome diftilled water; filter, and add the water to the nitrous folution: then neutralize the excefs of acid by potafh, taking care however, not to have an excefs of alkali, and add nitrat of lead as long as any precipitate takes place: wafh the precipitate in cold water, dry and weigh it. As the arfenical ores often contain fulphur, it is poffible that the arfeniat of lead thus procured, may be mixed with a little fulphat of lead: to decide this, digeft the powder in fome warm dilute muriatic or nitrous acid, and the arfeniat of lead will be diffolved, leaving the fulphat behind. 100 parts arfeniat of lead contain, of arfénic acid 33, oxyd of lead 63, water 4, and the 33 parts arfénic acid, denote 22 of the metal.

§ 3. *Reduction of Arfenical Ores, and Preparation of Crude Arfenic, and White Arfenic.*

Arfenic is a fubftance of fuch fmall value and fuch little demand, that none of the proper ores of this metal are wrought in the great; the whole of the arfenic of commerce being prepared in Saxony, by roafting the cobalt ores in the manufacture of zaffre. Thefe confift principally of arfenic, cobalt, iron, and a little fulphur; the firft and laft ingredients of which are got rid of by roafting: this procefs, inftead of being performed in the open air, is done in an oven, the flue of which runs horizontally to a confiderable diftance before it bends upwards. By this contrivance the arfenic and fulphur when liberated, are for the moft part depofited in the horizontal flue in the form of a greyifh meal, ftreaked with yellow (fuch portions as are neareft the fire being often melted into a femitranfparent cryftalline mafs). In this ftate it is called *crude arfenic*, or *flowers of arfenic;* the yellow ftreaks proceed from the fulphur uniting with the arfenic into orpiment: and befides this, it is alfo fullied with other impurities.

The *white arfenic* of commerce is prepared from the crude, by mixing this laft with potafh, or as fome advife, with lime, and re-fubliming. By this the fulphur and other impurities unite with the alkali, and the white oxyd is driven over into a heated receiver, where it melts into a heavy colourlefs tranfparent glafs: by expofure for a fhort time to the air this glafs becomes opaque, and refembles in its fracture the fineft white china; and it is in this ftate that the the white arfenic of commerce is found in our fhops and laboratories.

§ 4. *Preparation of Reguline Arfenic.*

The old method of procuring the regulus of this metal, confifted in mixing white arfenic with half its weight of black flux, one fourth part of borax, and the fame proportion of filings of iron or copper, and fufing the whole as quickly as poffible in a crucible. When the whole is grown cold, there will be found on breaking the crucible, a mafs of impure metallic arfenic, of a bluifh white colour and confiderable hardnefs and folidity. Probably this regulus was originally made from the crude arfenic, in which cafe the addition of iron or copper was for the purpofe of feparating the fulphur according to the procefs mentioned for martial regulus of ANTIMONY. (§. 4.—III.) It is obvious, however, that the arfenic muft contain a variable proportion of iron or copper when prepared according to this method, by which its external and chemical characters will be in fome degree modified. Another way of obtaining the regulus is recommended by Brandt, to which there can be no objection, upon the fuppofition that he ufed crude arfenic. He directs that white arfenic fhould be mingled with foap, and fublimed: in this operation the oil of the foap ferves to de-oxydate the arfenic, and the alkali to keep down any portion of fulphur that may have been combined with the arfenic.

The white arfenic of commerce being an almoft entirely pure oxyd of arfenic, the reduction of it into the metallic ftate is very eafily effected. The moft eligible way is to mix the white arfenic with any of the vegetable or animal expreffed oils, till it becomes of the confiftence of very foft glazier's putty; it is then to be made up into round or oblong pieces, and dropped into a Florence flafk, fo as not to adhere to to the fides. The flafk with its contents is to be put into a fand-bath, or over a gentle charcoal fire, and muft be heated very gradually as long as any thick vapours proceeding from the decompofition of the oil are given out. When thefe ceafe, the heat may be by degrees increafed till the bottom of the flafk becomes obfcurely red; fhortly after the flafk may be withdrawn from the fire, and when cold, upon carefully breaking it, there will be found in the neck and upper part of the veffel, a cruft of brilliant triangular cryftals of oxyd of arfenic, femi-tranfparent, and

of a yellowifh grey colour, below thefe there will be a thick amorphous cruft of regulus, and fome impurities will remain at the bottom. Let thefe products, except the impurities, be feparated from the fragments of glafs, and pulverized together with half their weight of charcoal; then re-fublime the whole as before, and the infide of the flafk will be found lined with a cruft and cryftals of pure and fhining regulus of arfenic. It is neceffary that thefe fublimations fhould be performed under a chimney, for the vapours that arife are intolerably fetid, and extremely noxious to the operator, bringing on in a very fhort time headach, ficknefs, and other unpleafant fymptoms. Inftead of a flafk, an earthen retort may be made ufe of.

§ 5. *External Characters and phyfical Properties of Reguline Arfenic.*

The frefh furface of arfenic is of a bright metallic luftre, and a colour between that of tin and lead; it very foon however tarnifhes by expofure to the air, becoming firft yellowifh, then flightly iridefcent, and laftly black, in which ftate it is alfo wholly deftitute of luftre. Its fracture is compact, granular; in hardnefs it is faid to be fuperior to copper, but it is fo brittle as to be reducible to power in a common mortar without any difficulty, being neither malleable nor ductile. It cryftallizes in octahedrons or tetrahedral pyramids. Sp. gr. = 8.31, according to Bergman, but according to Morveau = 5.76. It is not fenfible to the fmell when cold, yet the fingers after handling it acquire a flight metallic odour: it is manifeft to the tafte by a peculiar acrid flavour; and when heated to volatilization, diffufes a characteriftic fetid alliaceous odour.

§ 6. *Chemical Properties of Reguline Arfenic.*

I. Effects of Heat.

Arfenic, when pure, is incapable of being melted: in clofe veffels, at a heat inferior to that required for the fufion of tin, it begins to be volatilized, and is depofited in the upper and cooler parts unchanged in form or properties.

II. Effects of Atmofpheric Air.

Atmofpheric air at the ufual temperature is flowly decompofed by this metal, the oxygenous part uniting with the arfenic, and converting it into a black oxyd, as mentioned § 5. At a heat of about 350° Fahr. the abforption of oxygen is much more rapid, and vapours of white oxyd begin to be vifible, diffufing the well-known arfenical fmell. At a higher temperature combuftion takes place: thus if a veffel or crucible be made red hot, and a few pieces of arfenic be thrown in, a denfe white vapour is immediately produced, accompanied by a light blue flame, and in a fhort time the whole is volatilized. This experiment muft not be made in an iron ladle, for the affinity between the two metals at this temperature is fo great, that artificial mifpickel would be formed, and this being very fufible, the ladle would in all probability be found after the procefs to have a hole in its bottom.

III. Effects of Water.

Although arfenic is fo eafily oxydable, yet it does not appear capable of decompofing water; at leaft it may be immerfed in it for any length of time without exhibiting any figns of folution or oxydation; and a covering of this fluid or of alcohol is the beft prefervative of arfenic againft the tarnifhing effect of the air.

IV. Arfenic with Hydrogen.

This combination was firft difcovered by Scheele. If liquid arfenic acid be digefted with zinc, an effervefcence will take place; and the air thus difengaged, has a ftrong arfenical fmell, inflames by the contact of a candle, and depofits on the infide of the veffel a brown film, which is metallic arfenic. The fame gas may alfo be produced by granulated zinc in a hot folution of white arfenic in water with the addition of a little muriatic acid.

V. Arfenic with Phofphorus.

The union of thefe two fubftances was firft obferved by Margraaff, whofe experiments have fince been repeated and confirmed by Pelletier. Phofphuret of arfenic may be made in four ways: firft, by fubliming equal parts of phofphorus and white oxyd of arfenic, in which cafe, part of the phofphorus will be acidified at the expence of the metallic oxyd, while the remainder will combine with the metallic bafe; fecondly, by fubliming equal parts of reguline arfenic and phofphorus; thirdly and fourthly, in the humid way, by digefting equal parts of arfenic or oxyd of arfenic, with the fame weight of phofphorus in a flafk, containing a fufficient quantity of water. Phofphorated arfenic is volatilizable in a moderate heat, and is combuftible on hot coals, exhaling the mixed odour of its ingredients.

VI. Arfenic with Sulphur.

Both arfenic, and the white oxyd, are capable of uniting with fulphur, by means of fufion or fublimation, into a beautiful red or yellow mafs, according to the relative proportion of the ingredients. The yellow is called *orpiment*, or yellow fulphuret of arfenic, the red, *realgar*, or red fulphuret. The fulphur in the realgar is to the arfenic as 1 to 4 nearly, but in the orpiment as 1 to 9 or 10. Both preparations are fufible, and may be fublimed, but the realgar is more eafily melted, and with care may be obtained quite tranfparent, and of a bright red colour; hence it has been called *arfenical ruby, rubine d'arfenique*. The fp. grav. of orpiment, according to Bergman, is = 5.315; but of realgar, only = 3.225.

Thefe two fubftances have not been very accurately analyfed, and it is the opinion of feveral modern chemifts, that the differences between them does not depend fo much on the proportions of the fulphur and arfenic, as on the prefence of oxygen in the one, and its abfence from the other. Hence they call realgar, fulphuret of arfenic, and orpiment, fulphurated oxyd of arfenic. This appears, however, to be a miftake, for the following reafons; when regulus of arfenic and fulphur are mixed together, the combination takes place without the extrication of any gas, but when the oxyd of arfenic is fubftituted for the regulus, at the moment of combination a portion of the fulphur is converted into fulphureous acid gas, probably on account of a decompofition of the metallic oxyd. Further, it appears from the experiments of Bucquet, that by continued fufion orpiment is made of a much redder colour than before, by the volatilization of part of its arfenic; and as an additional confirmation, it may be mentioned that realgar, being fublimed either with metallic or oxydated arfenic, is converted into orpiment.

It is not very eafy to make realgar by the direct combination of its elements when they are in a ftate of purity, on account of the eafe with which they are volatilized before they have experienced the proper degree of heat. In Saxony, where orpiment and realgar are made in large quantities, the method is to fil an oven like that defcribed in § 3. with mifpickel and iron pyrites, proportioning the quantities of each according as realgar or orpiment is intended to be produced. Now the fulphur and arfenic contained in thefe minerals being in natural combination with iron, require for their fublimation a degree of heat far greater than they could fuftain without volatilization, if they were pure.

Sulphurated arfenic is wholly infoluble in water or alcohol. The nitrous and nitro-muriatic acids, efpecially when warm, take up the arfenic from the fulphur. The former of thefe,

however, except it is so concentrated as to act on the sulphur also, only takes up a portion of the arsenic from realgar, converting it into orpiment. Nitro-muriatic acid completely decomposes both the red and yellow sulphuret, hepatic gas being given out at the same time, a circumstance worthy of notice, as affording additional strength to to the opinion mentioned above, concerning the state of the metal in these compounds. Sulphuret of arsenic is also decomposed by distillation with two or three times its weight of *corrosive muriat of* MERCURY, the acid and oxygen of the mercurial salt uniting with the arsenic into corrosive muriat of arsenic, § 7.; and the metallic base with the sulphur of the orpiment, forming cinnabar.

In the dry way, the fixed alkalies decompose orpiment into alkaline sulphuret and arsenic, which latter sublimes; but if the alkali is in excess, the arsenic is in part detained as well as the sulphur. A solution of caustic potash in water being boiled with orpiment, dissolves it completely, but by the addition of an acid a yellow precipitate is thrown down, which probably is a *hydrosulphuret of arsenic.* Quicklime and orpiment also unite by boiling in water, forming an arsenio-sulphuret of lime, which is sometimes employed as a WINE-TEST.

VII. Arsenic with Oils.

Any of the expressed oils being triturated with arsenic, gradually dissolve it, and thus acquire a dark colour and consistence like salve.

VIII. Alloys of Arsenic.

Arsenic unites with almost all the metals, debasing the red and yellow ones, and destroying in a great measure the lustre of all the rest, except tin. It renders those which are malleable and ductile, brittle, and for the most part increases their fusibility and hardness. For other particulars, see the several metals.

§ 7. *Salts of Arsenic.*

1. Reguline arsenic is acted upon by sulphuric acid when concentrated and assisted by heat: if the operation be performed in a retort with a pneumatic apparatus, there will be produced a considerable quantity of sulphureous acid gas, and sulphur will sublime into the neck of the vessel. What remains behind is a white mass similar to oxyd of arsenic, but combined with a little acid. By the addition of a fresh portion of sulphuric acid, the sulphated oxyd is taken up; as the liquor cools, however, a precipitation of crystalline grains happens, and these are *sulphat of arsenic.* This salt is much less soluble in water than white arsenic; when exposed to the flame of a blow pipe, it fuses and begins to emit an arsenical smoke, but requires a much longer time for its volatilization than the simple oxyd. By repeated cohobation with sulphuric acid, the arsenic approaches more and more to the nature of arsénic acid, but always continues in some degree sulphated.

2. Nitric acid when hot is readily decomposed upon reguline arsenic, being itself changed into nitrous gas, and the metal becoming oxydated. An addition of dilute nitrous acid at a boiling temperature effects a complete solution of the residual oxyd, and the liquor by evaporation and cooling may be brought to deposit crystals of *nitrat of arsenic.* This salt being abstracted with fresh nitrous acid, and then heated red hot, is wholly converted into arsénic acid. Nitrat of arsenic is sparingly soluble in water, and with the blow-pipe exhibits nearly the same appearances as the preceding salt.

3. Oxymuriatic acid when pure, fresh made, and in the form of gas, exercises a very powerful action on the regulus of arsenic, and exhibits a very striking and beautiful appearance. For this purpose, let a common six or eight ounce phial be filled in the usual way with oxymuriatic acid gas procured from salt, manganese, and sulphuric acid, in order to have the acid as dry as possible (for the further securing of which, the gas produced about the middle of the process is the best); stop the mouth of the phial with a cork, and place it on a table in an upright position; then reduce some reguline arsenic to a fine powder, and cautiously opening the mouth of the phial, shake in from the end of a knife, or in any other convenient way, a little of the powder. As soon as it comes in contact with the gas, a white vapour will first appear, and will be immediately followed by ignition of the metal, which in its passage to the bottom of the vessel will appear like a stream of fire: this phenomenon may be repeated with successive portions of powder till the acid is almost wholly decomposed. At the bottom will be found a white acidulous oxyd of arsenic. Liquid oxymuriatic acid also is capable of dissolving reguline arsenic; but during this process, the metal being oxygenated at the expence of the acid, the result is muriat of arsenic.

4. Arsénic acid has a remarkable action on its own regulus, though the two appear to be incapable of combining into a proper salt. If the regulus is digested with the acid, its surface becomes shortly covered with a white powder, which is oxyd of arsenic. If the acid is kept in a state of fusion in a retort, and small pieces of the regulus are dropped in from time to time, an inflammation and sublimation of white arsenic will be manifest at each addition. Hence it appears that the oxygen of the arsénic acid quits this to combine with the regulus, till an equilibrium is produced by the one and the other being brought to a common state of oxydation.

These are all the acids which are known to act upon reguline arsenic, many others however are capable of combining with this metal, when previously brought to the state of white oxyd. The salts hence resulting we shall proceed to mention.

1. Muriatic acid when boiling will take up one third of its weight of oxyd of arsenic; a saline precipitate is produced by cooling, and if this is managed gradually, there are formed spicular crystals of *muriat of arsenic.* This salt sublimes wholly if exposed in close vessels to a moderate heat. Before the blow-pipe on charcoal it is decomposed in part and flies off, giving out at the same time the distinguishing odour of the metal. It is soluble, though sparingly, in warm water, and the solution is decomposable by an alkali, the oxyd of arsenic being thrown down.

Very dry and concentrated muriatic acid, or oxymuriatic acid, are capable of uniting with a much larger proportion of oxyd of arsenic than the liquid muriatic acid. This combination is called *butter of arsenic,* and is thus prepared: take one part of white arsenic, one and a half of red calcined sulphat of iron, and three parts of common salt; mix them accurately in a mortar, and distil in a glass retort from a sand bath. When the heat has been gradually raised so as to make the bottom of the retort nearly red, and nothing more comes over, the process is finished, and there will be found in the receiver two distinct liquors of different consistence. The lower one is of a clear iron brown colour, and is called *butter of arsenic;* the supernatant liquor is thinner, of a lighter yellowish colour, and is called *oil of arsenic.*

Butter of arsenic is a heavy thick liquor, excessively corrosive and poisonous; on exposure to the air it exhales a dense white suffocating vapour deliquiates, becomes turbid, and finally is spontaneously decomposed. When, instead of this gradual absorption of moisture, it is directly mingled with water, an immediate turbidness and precipi-

tation ensues of a white pulverulent matter, which was formerly taken for pure oxyd of arsenic; it still, however, as in the case with similar metal ic precipitates, retains a portion of acid; for by heating in a close vessel, a little butter of arsenic is sublimed. Liquid muriatic acid unites very sparingly and imperfectly with the butter; and if considerably diluted with water, produces a decomposition just in the same manner as pure water does.

Oil of arsenic, like the preceding, is decomposed in part by water or alcohol, but the precipitate is not so copious: it mingles with liquid muriatic acid without producing any turbidness. The addition of a carbonated alkali is followed by effervescence and the precipitation of oxyd of arsenic. By spontaneous evaporation it yields crystals of muriated arsenic, and a slight efflorescence of white oxyd of arsenic.

There are several other methods of obtaining the butter and oil of arsenic: thus, if orpiment is distilled with two or three times its weight of corrosive sublimate, the sulphur of the former unites with the mercury of the latter, and produces cinnabar, while the arsenic of the former combines with the oxygen and acid of the latter into the oil and butter of arsenic. It is remarkable, however, that corrosive sublimate is not decomposable by oxyd of arsenic; for when the two are distilled together, whatever be their relative proportions, the mercurial salt rises unchanged. Indeed the superiority in affinity of muriatic acid for oxyd of mercury over oxyd of arsenic is still more strikingly shewn by distilling butter of arsenic with oxyd of mercury, in which case a little butter of arsenic first comes over, then corrosive sublimate, and finally white arsenic. If, however, *reguline arsenic* is distilled with corrosive sublimate, the produce is butter of arsenic, a little calomel, and running mercury.

Although the salts of arsenic have not yet received that notice from chemists to which they are entitled, still there has arisen some difference of opinion respecting the combinations of this metal with muriatic acid, some affecting the butter of arsenic to be a proper oxymuriat, while others consider it as scarcely differing, except in concentration, from the muriat. From a careful collation of the scattered facts relative to this subject, it appears that there is no such salt as oxymuriat of arsenic, but that muriatic acid, when its affinities are not weakened by water, will take up a large quantity of arsenical oxyd forming the butter of arsenic; that when by the gradual or sudden addition of water, the affinities of this latter are brought into action, an unequal partition of the acid and oxyd takes place into a soluble and insoluble muriat of arsenic. Hence we have three distinct salts composed of muriatic acid and oxyd of arsenic: first, muriat of arsenic with the smallest proportion of metallic oxyd, this is soluble in water and crystallizable by cooling, and is also capable of sublimation without decomposition; secondly, muriat of arsenic with a larger proportion of metallic oxyd (butter of arsenic), decomposable by water, and not crystallizable; thirdly, muriat of arsenic supersaturated with the oxyd, insoluble in water, decomposable by sublimation.

2. Oxymuriatic acid gas passed into an aqueous solution of white arsenic, is itself decomposed into muriatic acid; and by distillation, the water and muriatic acid being drawn off, there remains in the retort solid arsénic acid. It is therefore probable that the three muriats of arsenic just mentioned differ from each other in the degree of oxygenation of the metallic base, as well as in the proportions of it that they contain; the first being the least oxygenated, and the latter the most so.

3. Fluoric acid, when digested on white oxyd of arsenic, dissolves a small proportion; and by evaporation and cooling, a granular crystalline salt is obtained, *fluat of arsenic*, the properties of which have not been examined into.

4. Boracic acid combines with white arsenic by means of water, but not in the dry way, according to Reuss. Equal parts of the oxyd and acid digested together in a little water are entirely dissolved, and afforded by evaporation *borat of arsenic* in powder or spicular crystals.

5. Phosphoric acid and oxyd of arsenic combine together without difficulty in the moist way, and afford crystals of *phosphat of arsenic*. This salt is very sparingly soluble in water, and is decomposable by heat, the oxyd being volatilized.

6. Liquid tartareous acid unites by digestion with oxyd of arsenic into a crystallizable salt, *tartrite of arsenic*; the properties of which are as yet in a great measure unknown.

7. Oxalic acid dissolves very easily a considerable quantity of white arsenic, and the liquor affords by evaporation and cooling prismatic crystals of *oxalat of arsenic*: these melt in a very gentle heat, the water of crystallization with part of the acid is evaporated, and the residue affords a very beautiful saline vegetation. Oxalat of arsenic is soluble both in water and alcohol, changes the colour of litmus tincture to red, and sublimes at a moderate heat; but at a higher temperature the acid is first destroyed and flies off, leaving behind the metallic oxyd.

8. Acetous acid, by long digestion and boiling with white arsenic, dissolves a small proportion, and deposits by cooling and evaporation small crystalline grains of *acetite of arsenic*, which are very sparingly soluble in water.

9. Benzoic acid, according to Trommsdorff, dissolves white arsenic with considerable ease, and forms with it *benzoat of arsenic*. This salt appears in the form of long slender radiating crystals, possessed of a sour and pungent taste, which effloresce in the air, are very soluble in boiling water, and are again for the most part deposited by cooling.

10. *Gallat of arsenic* is not known, nor does the tincture of galls, according to the chemists of Dijon, produce any alteration in a solution of white arsenic.

11. Prussiat of potash, when pure, throws down an abundant white precipitate from the solution of arsenic in muriatic acid. This is soluble in a large quantity of water, and by sublimation in the dry way affords a semi-transparent mass; it is probably a *prussiat of arsenic*, but has been as yet scarcely at all examined.

The order of affinity of the various acids for oxyd of arsenic is not ascertained with much certainty. Bergman arranges them in the following order; muriatic, oxalic sulphuric, nitric, tartareous, phosphoric, fluoric, arsénic acetous, and prussic acids.

§ 8. *Oxyd of Arsenic, or Arsenious Acid.*

Oxyd of arsenic is prepared in the large way according to the method already mentioned in § 3. When pure, it is of an opaque white colour; or if recently fused, is perfectly transparent and colourless. It crystallizes artificially (§ 4.) in three-sided pyramids, the vertical angle of which is generally deeply truncated; the crystals are transparent, of a dilute wine yellow colour, and not liable to effloresce or become opaque by exposure to the air, probably owing to their containing rather a smaller proportion of oxygen than the white arsenic of the shops. The sp. grav. of the fused oxyd is about $= 5$. It slowly excites upon the tongue a sweetish acid taste. It is the most volatile of any of the metallic oxyds, rising at 383° Fahr.

Pure water at the temperature of 60° Fahr. will dissolve about $\frac{1}{80}$ of its weight of this oxyd, but when boiling it takes up $\frac{1}{15}$, the greater part of which it retains even when cold; by evaporation, however, minute three-sided

pyramidal cryſtals are depoſited: the ſolution is clear and colourleſs. Alcohol alſo, when boiling, will diſſolve about $\frac{1}{70}$ or $\frac{1}{80}$ of its weight.

From many of its properties white arſenic ſeems to hold a kind of middle place between an acid and metallic oxyd: thus, it reddens litmus tincture, but turns ſyrup of violets green, and its aqueous ſolution is incapable of cauſing an effervefcence in the carbonated alkalies and earths. In the new chemical nomenclature it is denominated the arſenious acid (acide arſenieux, Fr.); and the ſalts that are formed by its combination with the alkalies, earths, and metals, are called arſenites. Theſe ſeem to hold nearly the ſame relation to arſénic acid and the arſeniats, as ſulphureous acid and the ſulphites do to ſulphuric acid and the ſulphats.

The white oxyd of arſenic is eaſily deoxygenated by carbonaceous matter, by hydrogen, phoſphorus, and ſulphur, as already mentioned § 4. and 6. and is reduced to the ſtate of reguline arſenic: its habitudes with acids are deſcribed § 7.

If to a ſolution of cauſtic pot-aſh in water there be added ſome finely powdered oxyd of arſenic, the whole combines together by a boiling heat into a thick, viſcid, ſcarcely fluid matter, of a brown colour, and nauſeous ſmell, which as it cools becomes ſolid and brittle. This was named by Macquer *liver of arſenic*, and in the modern ſyſtem has obtained the name of *arſenite of pot-aſh*. By long expoſure to the air it becomes deliqueſcent; it is readily ſoluble in water, but has not been made to cryſtallize. The addition of any of the acids to the ſolution cauſes an immediate decompoſition with a copious precipitation of oxyd. Cauſtic ſoda produces the ſame general effects on white arſenic as potaſh, except that the arſenite of ſoda is cryſtallizable. Either of theſe ſalts, on being ſubjected to a full red heat, is decompoſed; the greater part of the arſenic being volatilized in the form of a denſe white ſmoke, while the remainder in the ſtate of arſénic acid remains united with an exceſs of alkali. In the dry way, the white oxyd of arſenic melts together with the fixed alkalies, forming a maſs not eaſily decompoſable by heat. According to Bergman, potaſh is capable of thus fixing twice its weight of the oxyd, and ſoda three times its weight of the ſame.

When ammoniacal gas is paſſed two or three times over heated white arſenic, the two ſubſtances contract at length ſo intimate an union as to bear even fuſion without ſeparating from each other. In the moiſt way alſo, a combination takes place by the help of a gentle heat, which differs eſſentially from the common liver of arſenic in that the acids occaſion no precipitation. Theſe are ſingular facts, and the nature of the arſenite of ammonia is well worthy of more notice from chemiſts than it has yet obtained.

Quicklime and barytes combine by fuſion with oxyd of arſenic into a vitreous maſs which however becomes milky and opaque by the continued action of the air. In the moiſt way, lime and white arſenic being boiled together form a ſoluble arſenite of lime, from which a precipitate is thrown down on the addition of an acid. Neither magneſia, alumine, nor ſilex, appear capable of uniting with white arſenic by fuſion, but all or any of them combine into an eaſily fuſible maſs with the arſenites of potaſh, ſoda, lime, or barytes.

But few of the neutral ſalts have been examined with reſpect to their action on arſenious acid. The nitrats of potaſh and ſoda are decompoſed by heat converting the arſenious into the arſénic acid, and therefore this combination is treated of in § 10 (*Arſeniats*). The effect of white arſenic on acetite of potaſh, as recorded by Cadet and the other chemiſts of the academy of Dijon, is however too remarkable to be omitted. A mixture of theſe two ſubſtances being ſubjected to diſtillation, there firſt paſſed over a limpid liquor, with a ſlight arſenical ſmell; this changed the colour of ſyrup of violets red, cauſed an effervefcence in a ſolution of carbonated alkali, and rendered the liquor turbid. The next product was of a reddiſh brown colour, and filled the receiver with a denſe vapour of a moſt peſtiferous odour, different however from that of arſenic; towards the end of the proceſs, ſome reguline arſenic ſublimed into the neck of the retort. The red liquor, after being confined for three weeks in a ſtopped phial, was ſtill ſmoking, and exhaled the ſame deteſtable ſmell as before; it produced no alteration in ſyrup of violets, and occaſioned only a very feeble effervefcence with carbonated alkali, depoſiting a little flocculent ſediment: it occaſioned a white precipitate in a ſolution of corroſive ſublimate: being poured into a filter, in order to ſeparate a yellowiſh thick portion that had ſeparated from the reſt, ſcarcely had a few drops paſſed through, than a denſe ſuffocating vapour began to riſe accompanied by an ebullition at the edges of the veſſel, and immediately followed by a beautiful roſe-coloured flame which laſted ſeveral ſeconds.

A hot ſolution of arſenious acid diſſolves ſome of the metals, particularly copper, iron, and zinc; the differences, however, between theſe and the metallic arſeniats have not been aſcertained with much accuracy.

§ 9. *Arſénic Acid.*

The properties of the white oxyd of arſenic that have been mentioned in the preceding ſections, eſpecially its ready ſolubility in water, its cryſtallizability, its taſte, its habitudes with alkalies and metals, had long induced a ſuſpicion of its ſaline nature. This ſuſpicion was at length confirmed by Macquer's valuable diſcovery of the *arſenical neutral ſalt* (ſee § 10. arſeniat of potaſh); but chemiſts ſtill continued ignorant of the preciſe difference between this and the liver of arſenic (arſenite of potaſh). The illuſtrious Scheele firſt cleared up this difficulty, and pointed out a method of procuring the arſénic acid in a ſtate of purity, and uncombined with any other ſubſtances. Bergman's valuable eſſay on the ſame ſubject confirmed and extended the diſcoveries of his friend and countryman, and more recent experiments have brought new acceſſions to the intereſting facts already collected. Arſenic, as well as ſome others of the metallic bodies, is not only a combuſtible and oxydable, but alſo an acidifiable baſe. It combines with oxygen, in at leaſt three different proportions. By the ſpontaneous action of air and moiſture, at the uſual temperature, it is converted into the black oxyd, an additional portion of oxygen is abſorbed by the aſſiſtance of a higher heat, forming the white oxyd; and by means, that we ſhall now proceed to mention, this latter ſubſtance may be ſaturated with oxygen forming a perfect acid; the *arſenical*, or ARSÉNIC (*acidum arſenicicum*, or *arſenici*, *acide arſenique*, *arſenikſaure*).

The method recommended by Scheele for the preparation of arſénic acid is the following.—Take two parts of finely powdered white oxyd of arſenic, and put it into a capacious tubulated retort, adapted to a quilled receiver, and fixed properly in a ſand-bath; then pour in ſeven parts, by weight, of ſtrong and pure muriatic acid, and cloſe the tubulure of the retort; as ſoon as the acid begins to boil, the arſenic will be rapidly diſſolved; and when the whole is taken up, lower the heat, and add three and a half parts of concentrated nitric acid; the mixture will immediately begin to foam, and there will be a copious extrication of nitrous gas. The diſtillation is, at the ſame time, to be proceeding gradually, as long as any nitrous gas is produced; and when this ceaſes, one part more of the white oxyd of arſenic may

be added. As soon as this is dissolved, pour into the retort one and a half part of nitric acid, and a fresh effervescence will take place. The whole is now to be distilled to dryness, and towards the end of the process the heat must be increased till the bottom of the retort, with its contents, is red hot. After the retort is grown cold, it must be broken, and there will be found within it a saline mass, which is the dry arsénic acid. In order to preserve it in its solid state, it must be put into a dry, well-stopped phial. The proportion of acid thus procured is nearly equal to the quantity of white oxyd employed. The use of the muriatic acid in this process, seems to be merely that of a solvent of the arsenical oxyd, which is thus presented to the action of the nitric acid in a state of extreme division. The nitric acid is decomposed into nitrous gas and oxygen, the former of which flies away, while the latter is expended in acidifying the oxyd; by the subsequent red heat, the undecomposed residue of the nitrous acid, and the muriatic, are driven off in vapour, and the arsénic acid alone remains behind. It generally, however, corrodes the retort, in a greater or less degree; whence the solid acid, when boiled with water, leaves a small insoluble residue of silex.

Bergman's method is to make a hot saturated solution of white arsenic in muriatic acid, and to add double the weight of nitric acid. The effervescence, however, thus occasioned, is so great, that a considerable portion of the arsenic is driven over in the form of butter of arsenic, and the consequent produce of acid is much diminished, the quantity of this being estimated by Bergman at no more than 80 per cent. of the white oxyd employed. Weigleb, by repeatedly returning the liquor collected in the receiver into the retort with fresh nitric acid, obtained $112\frac{1}{2}$ of arsénic acid for every 100 of oxyd.

Another method of preparing this acid, also discovered by Scheele, is by oxymuriatic acid. Take one part finely pulverized black oxyd of manganese, and mix it with three parts of strong muriatic acid, in a tubulated retort, large enough to allow ample room for the effervescence of the mass: the retort is to be connected, in the usual way, with a Woulfe's apparatus, containing the white oxyd of arsenic and a little water. By a gentle heat, the muriatic acid becomes oxygenated at the expence of the manganese, and passes into the bottles in the form of oxymuriatic acid; here it is decomposed, and the muriatic acid unites with part of the arsenic, while the oxygen combines with another portion. This compound liquor being then gently distilled to dryness, and towards the end of the process the bottom of the retort being made red hot, a complete separation will take place; in the receiver there will be found distilled muriat, or butter of arsenic, and the saline mass remaining in the retort is arsénic acid.

A simpler way of procuring the acid, is to heat together the white oxyd of arsenic, with diluted nitrous acid, in a retort, and when the solution is complete, to add some strong nitric acid, and proceed to distillation: much nitrous gas will be given out, and some orange-coloured acid will come over into the receiver; return this upon the mass in the retort before it becomes dry, together with a fresh portion of strong nitric acid, and thus repeat the cohobation till the extrication of nitrous gas has almost ceased; then distil to dryness, and make the bottom of the retort red hot; all the remaining oxyd of arsenic and nitrous acid will be driven off, and nothing will be left behind but pure arsénic acid.

Besides the above processes, Pelletier has described another method of procuring the acid of arsénic. He mixes the white oxyd with nitrat of ammonia, and subjects the mass to distillation in a luted retort. It is necessary to begin with a very gentle degree of heat, for the decomposition of the ammonical salt is otherwise so rapid, that a large portion of the oxyd of arsenic is carried over into the receiver. But by proper management, the operation goes on more slowly and quietly; there passes over some nitrous acid, and by a slight increase of the heat, ammoniacal gas is also produced; towards the end of the process, a little white oxyd usually sublimes, and a solid vitreous mass of arsénic acid remains at the bottom of the retort, which, when heated red hot, becomes perfectly pure.

Arsénic acid is a solid vitreous mass, of a milky white colour: its sp. gr. according to Bergman, is = 3.391. It fuses at a temperature a little below red heat, and becomes a transparent colourless fluid; but by cooling, it again becomes milky. When raised to a full red heat, it begins to boil, and gives out a portion of its oxygen; being slowly converted into white oxyd of arsenic, which sublimes in proportion as it forms. If this experiment is performed in a covered crucible, after a time, almost the whole of the arsénic acid will be dissipated, and the residue will be found closely adherent to the sides of the vessel, having dissolved a portion of its earth, and being thus converted into a permanent glazing. Arsénic acid is wholly insoluble in alcohol; but has so strong an affinity with water, as to deliquiate by exposure to a moist air: it dissolves completely in three or four times its weight of water, and has not been obtained in a crystalline form, either by refrigeration or evaporation. It has a sour, caustic, metallic taste, and reddens litmus tincture, though it produces no change on syrup of violets. Charcoal powder, digested with the aqueous solution, exerts no chemical action whatever on it, but if the mixture is distilled to dryness in a close retort, as soon as the bottom begins to grow red hot, the whole mass takes fire with violence, and the acid is deoxygenated, a beautiful sublimate of reguline arsenic being found in the neck of the retort. Sugar, and oil of turpentine, or any of the expressed oils, are charred even by digestion with a saturated solution of the acid. Six parts of the acid digested with one of sulphur suffer no change, but when the mixture is distilled in a close retort, as soon as the water is driven off, and the sulphur begins to melt, a sudden combination takes place, accompanied by a copious extrication of sulphureous acid gas, and the whole contents of the retort rise almost instantaneously, and attach themselves to the upper part in the form of beautiful realgar. It combines with various alkaline, earthy, and metallic bases, forming a genus of compound salts, known in chemistry by the name of Arseniats. None of the acids appear to have any action on the arsénic, for though it is soluble in some of them, it may be separated again unchanged. It unites with the boracic and phosphoric acids by fusion, but neither suffers nor occasions any decomposition.

The order of its affinities, according to Pearson, are, in the moist way, lime, barytes, strontia, magnesia, potash, soda, ammonia, alumine, metallic oxyds, water.—In the dry way, lime, barytes, strontia, magnesia, potash, soda, metallic oxyds, ammonia, alumine.

§ 10. *Arseniats.*

1. *Arseniat of Potash.*

If a solution of arsénic acid is dropped into caustic potash, till the mixture ceases to change syrup of violets green, and turns tincture of litmus red; thus shewing an excess of acid; there will be obtained by evaporation a crystallizable salt, arseniat of potash. But if on the other hand potash be added to arsénic acid till the mixture turns syrup of violets green, but produces no change on tincture of lit-

mus, an uncryſtallized ſalt is the reſult, which being evaporated to dryneſs, again deliquiates on being expoſed to the air. Theſe varieties of arſeniated potaſh are, however, rarely made by the direct union of their component parts, but from the white oxyd of arſenic and nitre. The phenomena attending this proceſs we ſhall therefore firſt explain, before we enter upon an enumeration of the properties of the ſalt.

Let any quantity of nitre be melted in a crucible, the bottom of which is heated red, and ſmall portions of white oxyd of arſenic be projected at intervals, taking care not to add a ſecond portion till the effervefcence and diſengagement of the nitrous gas occaſioned by the former has ceaſed. By degrees the matter in the crucible, provided the heat is not augmented, will grow thick; and being then examined by ſolution and cryſtallization, will be found to redden litmus, and conſiſt of arſeniat of potaſh in a cryſtallizable ſtate, and ſome undecompoſed nitre. If, however, the maſs in the crucible is kept for a few minutes at a little higher heat, it will enter into perfect fuſion, and give out ſome nitrous gas; after a ſhort time it will again grow thick, and being then diſſolved in water, will turn ſyrup of violets green, and refuſe to cryſtallize, forming what Macquer and the old chemiſts call *Nitre fixed by arſenic.*

If a mixture of equal parts of nitre and white arſenic be put into a crucible (or ſtill better, into a Florence flaſk), and the flaſk be heated gradually in a ſandbath, till its bottom is obſcurely red, there will happen a very copious diſengagement of orange-coloured vapours; when theſe ceaſe, the veſſel is to be withdrawn from the fire, and will be found to contain a white ſaline maſs, which by ſolution in hot diſtilled water, and evaporation, will yield arſeniat of potaſh, formerly called after the inventor *Macquer's neutral arſenical ſalt.* When, on the contrary, two parts of nitre and one of white arſenic are ſubjected to the above treatment, the reſult is an uncryſtallizable deliqueſcent maſs, the alkaline arſeniat of potaſh. This may be converted into the cryſtallizable or acidulous arſeniat, either by the addition of arſénic acid, in which caſe the whole will be arſeniat of potaſh, or by ſulphuric acid, which neutralizing the alkali, the liquor will yield by cryſtallization arſeniat and ſulphat of potaſh. In oppoſition to theſe facts, which are mentioned by Bergman, Scheele, Macquer, and moſt modern chemiſts, Pelletier has recorded an experiment, which, though he draws no concluſions from it, ſeems incapable of being reconciled with the theory of an alkaline and acidulous arſeniat of potaſh. He mixed, according to the proceſs of Lefevre, two ounces of white arſenic with four of nitre, and put the whole into a large crucible, the mouth of which was then cloſed with a ſmaller inverted crucible pierced with a ſmall hole to give vent to the nitrous vapour. It was ſubjected firſt to a very gentle heat for three hours, and then expoſed to a red heat for eight hours longer. The matter thus prepared was a compact ſaline white maſs, eaſily ſeparating from the crucible, and weighing one gros leſs than four ounces. Being diſſolved in diſtilled water and filtered, there was ſeparated a gelatinous maſs, conſiſting no doubt of ſome of the potaſh combined with the earth of the crucible. The clear liquor that paſſed the filter afforded by evaporation cryſtals of arſeniat of potaſh, and the mother water conſiſted almoſt wholly of cauſtic potaſh, which united quietly with ſulphuric acid, and formed ſulphat of potaſh. Here therefore we have an example of the cryſtallized arſeniat formed in the midſt of cauſtic potaſh, a circumſtance wholly unaccountable if an exceſs of acid is neceſſary for this purpoſe.

Arſeniat of potaſh cryſtallizes in rectangular quadrilateral priſms, terminated by four-ſided pyramids. In cloſe veſſels it fuſes at a low red heat, but ſhews no ſigns of decompoſition; when made to boil violently in an open veſſel it gives out oxygen, and acquires alkaline properties. It neither effloreſces nor deliquiates in the air. It is ſoluble in about ſix parts of boiling water, and depoſits cryſtals by cooling. It is decompoſable by lime and barytes, either in ſolution or by fuſion, the acid quitting the alkali to unite with the earths. The ſulphuric, nitric, and muriatic acids, abſtract from it the alkaline baſe, ſetting the arſénic acid at liberty and forming ſulphat, nitrat, or muriat of potaſh. It decompoſes and precipitates almoſt all metallic oxyds from their combinations, forming inſoluble metallic arſeniats. In the dry way, it is decompoſed by charcoal, and the product is reguline arſenic of great beauty and purity, and carbonated potaſh. Sulphur, iron, and zinc, alſo decompoſe this ſalt, the reguline arſenic combining with one part of them, while the other is oxygenated.

2. *Arſeniat of Soda.*

According to Scheele, if ſoda is ſaturated with arſénic acid, cryſtals of arſeniat of ſoda are obtained, ſimilar in figure to thoſe of the preceding ſalt; however, the ſolution of them has no effect on litmus, but turns ſyrup of violets green. Some arſénic acid ſuperadded, takes away the cryſtallizability of the maſs, which, when evaporated to dryneſs, deliquiates in the air. Pelletier, by decompoſing nitrat of ſoda by oxyd of arſenic, in the manner already recited for preparing arſeniat of potaſh, obtained a permanent ſalt in truncated hexahedral priſms. The other properties of arſeniat of ſoda are unknown; probably, however, they are analogous to thoſe of the preceding article.

3. *Arſeniat of Ammonia.*

Liquid ammonia, ſaturated with arſénic acid, affords by evaporation a ſalt ſimilar in form to the rhomboidal cryſtals of nitrat of ſoda. It turns ſyrup of violets green, but produces no change on litmus; by a gentle heat it becomes opaque, and part of the ammonia flying off it exhibits an exceſs of acid. In this ſtate it forms long acicular acid cryſtals, which deliquiate in the air. When diſtilled, it firſt gives out ſome ammoniacal gas, then fuſes, and again becomes ſolid after it has parted with ſome oxyd of arſenic which ſublimes. By a further increaſe of temperature it again becomes fluid, and is now found to be wholly changed into arſénic acid. Muriat of Ammonia is decompoſed by diſtillation with three parts of arſénic acid. There firſt riſes muriatic acid, then ammoniacal gas, afterwards oxyd of arſenic, and arſénic acid remains behind; hence it is obvious that part of the arſénic acid is deoxygenated at the expence of a portion of the ammonia.

4. *Arſeniat of Lime.*

If arſénic acid is dropped into lime water, a white precipitate is thrown down, which is reſoluble in a freſh portion of acid; the ſolution being now evaporated, ſmall cryſtals are obtained of arſeniat of lime. Another way of procuring this ſalt, is by digeſting chalk in arſénic acid. An effervefcence enſues, and afterwards by cooling, copious cryſtals are depoſited. Arſeniat of lime is ſparingly ſoluble in water, and the ſolution is decompoſed by ſulphuric acid, ſulphat of lime being precipitated. The affinity of arſénic acid for lime, is alſo inferior in the moiſt way to nitric, muriatic, or even acetous acid. Yet nitrat, muriat, and acetite of lime are decompoſable by means of double affinity, by the uncryſtallizable arſeniat of potaſh, and the arſeniats of ſoda and ammonia, arſeniat of lime being in all theſe caſes precipitated. This ſalt, if heated ſtrongly in a cloſe crucible, enters into fuſion, forming a white enamel-like maſs, but without undergoing any decompoſition; by mixing with charcoal and ſubſequent heating, the greater

part of the acid is oxygenated, and reguline arſenic is ſublimed. Arſénic acid in the dry way has ſo powerful an affinity for lime, as to be capable of uniting with this earth to the excluſion of ſulphuric, fluoric, and nitric acids.

5. *Arſeniat of Magneſia.*

Acid of arſenic, when digeſted upon magneſia to ſaturation, forms a coagulum; this being diſſolved in a freſh quantity of arſénic acid, and evaporated, yields a jelly which by further privation of its moiſture is converted into an uncryſtallizable viſcous maſs. The ſulphat, nitrat, muriat, and acetite of magneſia, are not decompoſable by arſénic acid, but readily ſo by the alkaline arſeniats; the precipitate thus produced is inſoluble in water, but readily ſo by acids. When heated in a cloſe veſſel with charcoal, it exhibits the ſame phenomena as arſeniat of lime.

6. *Arſeniat of Barytes.*

This ſalt may be obtained in an earthy form, according to Scheele, by digeſting the acid upon barytes; at firſt the barytes diſſolves readily, but when the acid is ſaturated, a ſpontaneous precipitation of arſeniat of barytes takes place. Fourcroy informs us, that it may be procured in a cryſtalline form by mixing a warm concentrated ſolution of acetite of barytes and arſeniat of potaſh; a decompoſition takes place, and bright ſpicular needles of arſeniat of barytes are depoſited. In the moiſt way this ſalt ſeems undecompoſable except by ſulphuric acid and the eaſily ſoluble ſulphats. In a full red heat, however, even ſulphat of barytes is decompoſed by arſénic acid, the ſulphuric acid being volatilized.

7. *Arſeniat of Alumine.*

Moiſt earth of alum is readily ſoluble in arſénic acid, and by evaporation it yields a gummy uncryſtallizable maſs. The alkaline arſeniats will occaſion a precipitate in ſulphuric, nitric, and muriatic acids, previouſly ſaturated with earth of alum, and this precipitate is ſoluble in acids, though not ſo in water. It muſt however be remembered, that the earth precipitated from ALUM by an alkali is not pure ALUMINE, and therefore that the preparation here deſcribed is not arſeniat of alumine. Scheele indeed expreſsly mentions, that the ſolution mixed with charcoal, and evaporated to dryneſs, and then ignited in a cloſe veſſel, yields a ſublimate of orpiment, together with reguline arſenic and ſulphureous acid, and that the reſidue, when diſſolved in ſulphuric acid, depoſits after a time ſome cryſtals of alum. The arſénic acid, even by a long digeſtion with white clay, does not take up any portion of it. One part of clay and four parts of acid combine by fuſion into a vitreous maſs; and this, by being again heated with charcoal, affords a beautiful ſublimed regulus of arſenic.

The combinations of ſtrontia, and the other earths with the arſénic acid, have not as yet been examined. The metallic arſeniats will be found under the ſeveral metals.

§ 11. *Hiſtorical Notice concerning Arſenic.*

The native ſulphuret of arſenic, was the only one of the arſenical ores known to the ancients. Ariſtotle ſpeaks of the Σανδαραχη; and his pupil Theophraſtus, in his treatiſe on minerals, mentions the Αρρενικος, corrupted afterwards by Dioſcorides and others into Αρσενικος. Pliny alſo, in his Natural Hiſtory, deſcribes the arſenicum, auripigmentum, and ſandaracha. The Syrian orpiment, probably from its colour, was ſuppoſed to contain gold, and an ineffectual attempt by order of the emperor Claudius to extract this metal from it, is recorded by the Roman naturaliſt juſt mentioned. The ſandaracha of Pliny is realgar, being repreſented by him as friable, of a ruddy colour, and analogous to litharge. His arſenicum is expreſsly ſaid to be of the ſame ſubſtance as ſandaracha, and is thus deſcribed. "The colour of the beſt is ſuperior even to gold; the inferior ſorts are paler, or elſe approach to the hue of ſandaracha. It is of a ſcaly texture." The two laſt do not appear to have been conſidered of the ſame nature as auripigmentum: and the only uſe to which they were applied, was that of a cauſtic in medicine, and a pigment. The firſt mention of white arſenic is in the works of Avicenna, who lived in the 11th century. Paracelſus affirms, that arſenic ſublimed with egg-ſhells becomes like ſilver; and in 1673, Lemery publiſhed the method of obtaining the regulus by ſublimation from a mixture of white arſenic, fixed alkali, and ſoap. Albertus Magnus and Beccher conſidered arſenic (by which they meant the white oxyd) as of a ſaline nature. Kunkel was alſo of the ſame opinion; and Macquer, by his diſcovery of the arſenite and arſeniat of potaſh, demonſtrated that in theſe combinations it held the place of an acid. Finally, Scheele proved, that the baſe of arſenic (according to the Stahlian theory then in vogue) was not only ſimilar to, but was actually an acid, by diſcovering the method of obtaining it in an uncombined ſtate.

Arſenic being found in the ores of many metals, often ſerving as a mineralizer to them, and adhering with great obſtinacy to them even when brought into the ſtate of regulus, was long conſidered, like mercury, as an eſſential component part of metallic ſubſtances, nor was this opinion abandoned till the celebrated eſſay of Monnet in reply to a prize queſtion propoſed by the Royal Berlin Academy, in 1773, on the nature and peculiar agency of arſenic in the formation of metals. In this treatiſe he ſhews arſenic to be a peculiar metal, eſſentially differing from all others, and inſtead of being a neceſſary component part of them, is often totally abſent, and when preſent is ſo far from perfecting them, that it always deteriorates and obſcures their characteriſtic properties.

§ 12. *Uſes of Arſenic.*

In the reguline ſtate, it is uſed to whiten COPPER, and enters as an ingredient in ſeveral kinds of SPECULUM METAL. Oxyd of arſenic is employed as a poiſon for rats and other vermin, and a flux in GLASS-*making*. Orpiment and realgar are of extenſive uſe in DYING and CALICO-PRINTING, and as a pigment. For the deleterious properties of arſenic, and its medical uſes, ſee the next article.

Plinii Hiſt. Nat. Bergman's Eſſays. Scheele's Eſſays. Pelletier, Memoires de Chimie, vol. i. Encycloped. Method. art. Arſenique. Fourcroy, Syſt. des Connoiſſ. Chem. vol. v. Macquer's Chemiſches worterbuch, art. Arſenik. Gren's Syſtematiſches handbuch der Chemie, vol. iii.

ARSENIC, *in Pharmacy, and its Operation upon the Human Body.*—Arſenic is perhaps of all natural ſubſtances, that which exerts the moſt virulent and dreadfully active operation upon the living animal, when taken into the ſtomach or any other part of the ſyſtem.

We are, unfortunately, too familiar with its effects as a poiſon; its cheapneſs and abundance rendering it eaſily acceſſible to malevolence, or obnoxious to careleſſneſs, and the hiſtory of almoſt every year adds to the number of ſufferers from this formidable mineral.

Neverthelefs, as every poiſon, when judiciouſly managed, may be converted into a powerful medicine, ſeveral very ſkilful practitioners have attempted, and not without advantage, to add this ſubſtance to the materia medica, and hence the effects of arſenic become important to the phyſiologiſt in a double point of view, both that he may relieve and counteract them, when they operate as a poiſon; and manage them with judgment and caution, when they are intended to cure diſeaſe.

We may begin by obſerving, that all the preparations of arſenic appear, as far as experience goes, to operate in a ſimilar manner, though ſome with much more activity than others, in proportion to their quantity; and likewiſe it is fully aſcertained, that ſulphur moderates the operation of this metal in a very ſtriking manner, as indeed it does that of all the other metallic medicines. This comparative mildneſs of the ſulphuret may be the reaſon why the native orpiment and realgar have been employed medicinally for ages by ſome of the oriental nations, particularly, among other caſes, as an antidote to the bite of the cobra, and other venomous ſerpents; and we may remark, that the native arſenical ſulphures (as obſerved by Hoffman, and confirmed by ſubſequent experiments) are much milder and ſafer in their operations, than any of the artificial combinations of theſe two minerals.

When the active arſenical ſalts (the white arſenic for example) have been taken into the ſtomach in the quantity of a few grains or upwards, the moſt dreadful conſequences are obſerved to ſucceed: theſe are, firſt, a moſt horrible and almoſt indeſcribable anxiety at the pit of the ſtomach, to which ſucceeds a very acute burning pain in this organ, generally attended with violent retching and vomiting, whereby, indeed, the life of the ſufferer is ſometimes preſerved, owing to the rejection of the arſenic; this is often followed with ſevere purging, and the pain proceeds with increaſed virulence, to the bowels and almoſt the whole of the alimentary canal; to this ſucceed in a ſhorter or longer time convulſive tremors of the limbs, cold ſweats, and a very ſudden and characteriſtic ſwelling of the emphyſematous kind, which puffs up the face, the neck, and at laſt every other part of the body. If no relief be obtained from theſe dreadful ſymptoms, they quickly proceed to the deſtruction of life; the unhappy ſufferer becomes inſenſible to ſurrounding objects, lying on his belly, with every muſcle diſtorted by the violence of the pain, his hands clenched, his eyes bloodſhot and glaſſy, his jaws now immoveably fixed, and unable to ſwallow either ſolids or liquids, his limbs convulſed with ſevere cramps, his face and neck ſo much ſwelled that the features can hardly be recognized, till at laſt death terminates his agony. On inſpecting the body after death, the ſtomach is always found highly inflamed, partly gangrenous, and often actually coroded by ſphacelated ſpots. The ſame inflammation and partial mortification alſo extends in moſt caſes to parts of the ſmall inteſtines. The body is ſaid to putrefy with remarkable rapidity.

Even when perſons have recovered from poiſoning by arſenic, they feel its effects long after in griping pains, tremors of the limbs, partial paralyſis, loſs of appetite, and often a lingering hectic fever, which remain for a conſiderable time, and without great attention to health, are apt materially to injure the conſtitution. An expoſure to the fumes of arſenic occaſions ſimilar accidents, particularly griping, bloody urine, and contraction of the body, and ſometimes a general eruption like the nettle-raſh; and hence in all chemical operations with this dangerous metal, the operator ſhould be particularly cautious of avoiding its noxious fumes.

Arſenic when applied to any wounded or ulcerated ſurface of the body, is equally liable to produce the above-mentioned ſymptoms in a greater or leſſer degree; but as the firſt that appear are generally pains in the ſtomach and bowels, and ſwelling of the face, ſufficient warning is hereby given to withdraw the cauſe of them.

A variety of remedies againſt the poiſon of arſenic has been propoſed, all of which are intended to fulfil theſe two indications, to remove the noxious ingredient, and to protect the alimentary canal from its baneful operation. The firſt object is to get rid of the poiſon by moſt copious vomiting and purging; and for this purpoſe all the ſubſtances known to produce theſe effects, may be employed with the greateſt freedom. It has been thought that the rougher mineral emetic and purgative medicines ſhould be avoided, and certainly the milder vegetable ſubſtances appear the moſt eligible; but it is of ſuch infinite conſequence to apply an *immediate* remedy, that the preference due to one over another medicine can hardly ever be equivalent to the miſchief incurred by allowing this moſt corroſive and deleterious of all poiſons to remain a moment longer in the ſtomach than can be avoided. Hence the firſt emetic medicine at hand is always the beſt, nor ſhould the mechanical means of exciting vomiting, as by thruſting a feather down the throat and the like, be neglected. In the intervals of vomiting, the ſtomach ſhould be deluged with any mild mucilaginous liquid that is at hand; milk, gruel, linſeed tea, broth, oil of any kind, or even warm-water, in the largeſt poſſible quantity, ſhould be taken, and where the arſenic itſelf excites conſtant vomiting, as is often the caſe, no other remedy than theſe mucilaginous or oily liquids is required. Theſe ſhould be aſſiduouſly perſevered in till the burning pain and other ſymptoms produced by the arſenic are removed, and only the ſoreneſs conſequent to ſuch a violent exerciſe of the alimentary canal remains; after which a cautious and judicious uſe of opiates will prove of material benefit: but the ſtate of health will require much attention for a conſiderable time, before the conſtitution can entirely recover the effects of ſo rude a ſhock. When the poiſon has remained ſo long in the ſtomach that the ſufferer lies inſenſible, racked with pain and unable to ſwallow, recovery ſeems to be hopeleſs; in ſuch caſes, the moſt probable method of exciting vomiting is to lay ſome tartar emetic upon the tongue, part of which may perhaps be carried by the ſaliva into the ſtomach, and relieve it from the poiſonous mineral.

Some ingenious men have endeavoured to diſcover an antidote to arſenic, in the proper meaning of the term; that is, a ſubſtance which may prove a peculiar corrective to its baneful effects, by uniting with it when in the ſtomach, and deſtroying its acrimony. The well-known effect of ſulphur to mitigate the operation of all metallic bodies, readily ſuggeſted this as the deſired remedy, and the liquid alkaline ſulphuret was propoſed by Navier, an eminent phyſician of Chalons in France. Fourcroy has ſuggeſted the liquid hydro-ſulphures (or ſolutions of ſulphurated hydrogen in water, of which the ſulphurated mineral waters are familiar examples) as an improvement on Navier's remedy. Experience, however, has not confirmed the utility of either of theſe preparations. It is true, that if the poiſon and the antidote were previouſly mixed, and in a ſtate of ſolution, the former would be diſarmed of its terrible powers; but to truſt to the chance of a mere chemical operation in an organ ſo irritable as the ſtomach, ſo dreadfully ſuſceptible of active inflammation, and actually ſuffering under a violent injury which is haſtening the deſtruction of the whole ſyſtem, is to carry the ideas of a laboratory much beyond the bounds of ſober prudence and ſound practice.

It has been urged, however, that after the immediate danger from arſenic has been removed by the liberal uſe of emetics and emollient liquids, much advantage may be derived from the uſe of the liquid ſulphurets. But at this period we have not (in all probability) any of the arſenic to remove, but only the inflammation, the effects of arſenic, and on what ground can ſulphurated hydrogen be ſuppoſed to be of uſe in inflammation of the ſtomach and bowels?

The medical chemiſt is ſometimes called upon by the magiſtrate to aſcertain the preſence or abſence of arſenic in the ſtomach of perſons who have died with ſome of the vio-

lent ſymptoms above deſcribed. Some of the appearances, on diſſection, have been already mentioned. The preſence of arſenic, in ſubſtance, in the ſtomach, is thus aſcertained: firſt, make a ligature round the lower part of the oeſophagus, and another at the pylorus, to prevent any of the contents of the ſtomach from ſpilling; then take out this organ, empty its contents in a baſon, and rinſe the inner ſurface with a little cold water, which add to the other contents. As white arſenic, in ſubſtance, is generally that which is found after death by this poiſon, it will be ſeen in the form of a heavy white powder, from which the ſlime, and other contents of the ſtomach, may be waſhed off by repeated affuſions of cold water, which waſhings, however, ſhould not be thrown away, but added to the liquid contents. Then let the powder be ſubmitted to the following experiments: boil a portion of it in a Florence flaſk, in a few ounces of diſtilled water, and filter the liquid ſolution; add to a part of the clear liquid ſome water ſaturated with ſulphurated hydrogen gas, or a few drops of ſulphuret of ammonia, and if arſenic be preſent, a golden yellow ſediment will fall down, which will appear ſooner if a few drops of acetic acid be added; add to another portion of the ſolution a ſingle drop of a weak ſolution of carbonate of potaſh, and afterwards a ſolution of ſulphate of copper, when the arſenic will be indicated by a yellowiſh green precipitate, ſimilar to that which is known in chemiſtry by the name of *Scheele's green*; collect the ſediments and dry them, or if there is any of the powder to ſpare, take a portion of this, lay it upon red hot charcoal, when it will be entirely diſſipated in a white denſe vapour, having the garlic ſmell peculiar to arſenic.

But a portion of the white powder ſuſpected to be arſenic ſhould be reduced to the metallic ſtate, which may be done in the following neat manner, propoſed by Dr. Black: mix it with two parts of dry carbonate of potaſh, and one of powdered charcoal; procure a tube eight or nine inches long, and one-ſixth of an inch in diameter, of thin glaſs ſealed hermetically at one end; coat the cloſed end with clay for about an inch, and let the coating dry; then put into the tube the mixture of the powder and the flux, and if any of it ſhould adhere to the inner ſurface, let it be bruſhed down by a feather; ſtop the open end of the tube looſely with a cork, and gradually heat the ſealed end only, on a chafing-diſh of hot charcoal. The arſenic, if preſent, will then riſe to the upper part of the tube, on the inner ſurface of which it will form a thin, brilliant, metallic coating, whilſt a portion will eſcape in garlic ſmelling fumes. When nothing more riſes from the heated end, break the tube, and ſcrape off the metallic cruſt formed on the upper part. Of this, lay a part on heated iron, when it will totally exhale in a denſe ſmoke, with the peculiar arſenical ſmell; put another part between two poliſhed pieces of copper (halfpence, for example, rubbed quite bright), bind them together with wire, and expoſe them ſlowly to a low red heat; if the encloſed ſubſtance is arſenic, it will leave a white ſtain on the copper.

If it ſhould happen that no white powder is found in the ſtomach, the liquid contents, when filtered along with the waſhings, ſhould be evaporated to dryneſs, and the reſidue examined in the ſame manner as the white powder; but this would be a work of greater difficulty on account of the caſual mixture with the other contents of the ſtomach.

By theſe means the preſence of arſenic, even in very ſmall quantity, may be detected by any one tolerably verſed in chemical experiments; but, for greater ſecurity, it may be adviſable to perform ſeparate and parallel experiments with the white arſenic of the ſhops, and compare the reſults and appearances.

It is a matter of common obſervation, that no vegetable or mineral poiſon, however virulent, exiſts, which in diminiſhed quantity and by prudent precautions may not be converted into a valuable remedy. This obſervation will apply even to arſenic, and we have the moſt reſpectable teſtimony to its value in the cure or relief of ſome complaints which entitles it to conſiderable notice. The medicinal uſe of the ſulphurets of arſenic may be traced back to very early times, and the Greeks and Romans appear to have uſed it with conſiderable freedom. Dioſcorides obſerves that the arſenic (ἀρσενικόν) is found in the ſame minerals which produce the ſandarach. The beſt for medicinal purpoſes, he adds, is of a golden colour, unmixed with any other ſubſtance, which eaſily ſeparates into ſcales, and comes from Myſia on the Helleſpont. An inferior ſort comes from Pontus and Cappadocia. It is prepared by roaſting on hot coals, with conſtant ſtirring till it takes fire, and alters in colour, when it is to be cooled and carefully pulverized. The ſandarach is prepared in the ſame manner as the arſenic or orpiment, and poſſeſſes the ſame virtues. When taken internally, they have a violent corroſive and aſtrictive operation, exciting a burning on the ſkin, and cauſing the hair to fall off. Theſe arſenical powders were uſed principally as external applications, mixed with pitch, oil, or fat, againſt a variety of cutaneous complaints, itch, phthiriaſis, and other defedations of the ſkin, and alſo to ulcers of the noſtrils and mouth, and condylomata.

Much attention has been beſtowed in modern times to the power ſaid to be poſſeſſed by arſenic of relieving or curing cancers, when employed both as a topical application, and taken into the ſtomach. The progreſs of this diſorder is ſo dreadful, and the remedies uſually employed have proved ſo inadequate to ſtop its ravages, that any medicine, however ſevere, may be employed without cenſure, which affords a chance of permanent relief. We have ſtill to regret that the flattering hopes of a cure, and the real benefit often produced by this metal, have not been confirmed by frequent experiment; but the virtues of this remedy, however, are too important to be neglected. Several medical practitioners and empirics have gained much credit for ſuppoſed cures of cancers by remedies which appear to have been arſenical; and Mr. Juſtamond, in his valuable Surgical Tracts (London, 1789), gives the recipe of an arſenic cauſtic, called "the earl of Arundel's receipt to cure a cancer," and found in the Harleian MSS. which appears to have been divulged by a woman in the lower order of people, in the year 1638, whoſe father had long employed it for the cure of cancers.

Mr. Juſtamond, in his ingenious work above quoted, gives the hiſtory of many caſes of cancer in different ſtages, in which the following arſenical preparations were topically applied:

1. The earl of Arundel's receipt above mentioned, compoſed of one ounce of yellow arſenic, and half an ounce of bole armenic; or elſe of one ounce of the yellow arſenic, half an ounce of the red precipitate, and half an ounce of bole armenic.

2. A ſulphuret of arſenic, formed in the following way: Take four pounds of ſulphur, and one pound of white arſenic, mix and put them into a glaſs retort, on a ſand heat, and lute to the retort a long neck and receiver: raiſe the fire gradually till the mixture be fuſed: reject the ſublimed portion, and referve the fixed matter beneath, which muſt be finely levigated.

3. A mixed ſulphuret of arſenic and antimony, formed by melting together in a crucible, with a very moderate heat, the native black ſulphuret of antimony (or the common an-

timony of the ſhops), with white arſenic, in proportions varying according to the intention; being two parts of arſenic to one of antimony, where a violent arſenical cauſtic is wanted; and two parts of antimony with one of arſenic, where a milder eſcharotic is required.

Mr. Juſtamond began the above arſenical application, to the open or ulcerated cancers, which he uſed in the form of powder or ſcrapings, laid to the moſt ulcerated parts, whilſt he frequently moiſtened the hard retracted edges of the wound with a ſolution of muriated iron, with ſal ammoniac.

The immediate effect of the arſenic was to give a moſt acute and burning pain, which conſtantly attended every freſh application, and probably would be hardly tolerable to any, but to thoſe who are ſuffering under one of the moſt dreadful, haraſſing, and hopeleſs diſorders which ever come under the care of the ſurgeon. The firſt beneficial effect of the arſenical powder, was to correct, and almoſt entirely to remove the ſickening ſtench which attends theſe ſpecies of ulceration; and this was invariably the caſe, even when it failed to give any other relief. Afterwards the powder (where ſucceſsful) evidently improved the condition of the ſore, and by repeating it daily, with much perſeverance and attention, Mr. J. happily ſucceeded in producing a complete cure. It was only, however, in one or two inſtances that this was effected; and in others, the poiſon of the arſenic abſorbed into the ſyſtem, produced its baneful operation with ſo much rapidity, bringing on partial palſy, and ſevere pain with cramp in the bowels, that he was obliged inſtantly to diſcontinue it; with the unpleaſant feeling, that he had added to the already diſeaſed conſtitution of his patient, the ſevere diſorder occaſioned by the arſenical remedy itſelf. Mr. Juſtamond then made a trial of the ſtronger arſenical cauſtic (two parts of arſenic fuſed with one of antimony), to ſchirrous tumours of the breaſt, before they had proceeded to ulceration, with the view of *turning them out* entire, or as it were diſſecting them out by cauſtic, inſtead of the knife. In this he followed the example of Guy and Plunkett, who had been celebrated for this ſpecies of operation, an operation only to be undertaken when the patient is too timorous to ſubmit to the ſafer and more expeditious uſe of the knife. Mr. J. mixed the arſenical cauſtic with an equal weight of opium, brought the powder to the conſiſtence of an ointment by the yolk of an egg, and having the day before ſeparated the cuticle of the tumour by lunar cauſtic, he applied the arſenic over the whole ſurface. The pain was very great for twenty hours, after which it ſubſided. After ſome days the tumour began to ſeparate, and by repeating the cauſtic round the ſeparating edges, the ſchirrous gland, in about two months, "came out entire as a nut out of its ſhell, or as if it had been cleanly diſſected with a knife."

We ſhall proceed to enumerate ſome of the other noted arſenical preparations, employed externally to cancers and ſchirrous tumours. The following is given as Plunkett's celebrated arſenical cauſtic, with which the inventor uſed to extirpate ſchirrous tumours before they had arrived to ulceration.

4. Take of the leaves of the ranunculus acris (crowfoot), and of the flammula vulgaris (leſſer crowfoot, alſo a ſpecies of ranunculus), of each one ounce; of white arſenic levigated, one drachm; of flowers of ſulphur, five ſcruples. The two former plants being freſh gathered and bruiſed, the arſenic and ſulphur are to be added, and the whole beaten into a paſte, which is to be formed into balls, and dried in the ſun. When uſed they are to be beaten up with yolk of egg, and applied on a piece of pig's bladder to the ſurface of the tumour. This is to remain till the eſcharotic ſeparates ſpontaneouſly. The ranunculus, which is an acrid plant, is not here an uſeleſs addition, as it aſſiſts in ſeparating the cuticle, and till this is done the arſenic is ſcarcely able to act.

5. The arſenicum citrinum (*gelber arſenik*) employed at Vienna, is one of the ſtrongeſt of theſe preparations, being compoſed of ten parts of arſenic ſublimed with one of ſulphur. When uſed, the ſcrapings of it are laid on the cancerous ulcer till it is conſumed. The pain which it occaſions is moſt ſevere.

Mr. Febure's arſenical remedy (*Remède éprouvé pour guerir radicalement le Cancer occulte ou ulceré*, Paris, 1775), which excited much attention at the time, is the following:

6. Take one pint of water; one ounce of extract of cicuta; three ounces of Goulard's extract; one drachm of liquid laudanum; and ten grains of arſenic; mix them into a liquid, with which the cancer is to be ſmeared every morning and evening.

Laſtly, of the external applications, we may mention the following, which is ſimple, and probably as efficacious in ulcerated cancer as any of the preceding.

7. Take a ſolution of white arſenic in water, in the proportion of one grain to two pints, mix it with crumb of bread into a poultice, and apply it to the open ſore.

Febure appears to be the firſt who ventured to recommend the *internal* uſe of arſenic in the cure of cancer; a practice which has rarely been openly followed, though probably this mineral forms the baſis of many of the empirical remedies for this diſeaſe. Febure's internal arſenical medicine is the following:

8. Take of white arſenic, two grains; of ſyrup of chicory with rhubarb, half an ounce; of water, one pint. Of this one table ſpoonful is given every morning and evening, in an ounce of milk, with half a drachm of ſyrup of poppies. The doſe is to be gradually increaſed as the patient can bear it.

Mr. Juſtamond alſo was able to give internally as much as five grains of the arſenical ſulphuret (N° 2.) daily, without injuring the patient.

The inference which the reader will be diſpoſed to draw from all that we have given, concerning the efficacy of arſenic in cancerous complaints, will not probably be very encouraging to its uſe. The actual pain attending its application is always very acute, though perhaps not more ſo than the diſeaſe itſelf; but the quantity of the remedy here requiſite, either for external or internal uſe, is ſo conſiderable, as to incur great danger of poiſoning the conſtitution irremediably, and inducing calamities almoſt equal to thoſe which it is deſigned to counteract.

With more ſatisfaction we can conclude our account of this mineral, with a hiſtory of its employment in another obſtinate and often dangerous diſorder, in which it promiſes very great advantage, unattended with any conſiderable riſk where managed with great prudence and diſcretion. This is, in obſtinate and lingering agues, ſuch as have reſiſted ordinary remedies, and are proceeding gradually to undermine the conſtitution by their periodical and repeated paroxyſms.

We owe the introduction, or at leaſt the publicity of this remedy to Dr. Fowler's highly valuable ſeries of experimental caſes, undertaken in the Stafford infirmary, in 1784, and publiſhed in the following year. The circumſtance that directed his attention to this remedy, was the very great ſale and ſucceſsful operation of certain *patent ague drops*, which were (probably with reaſon) ſuppoſed to be a preparation of arſenic.

Dr. Fowler's arfenical folution is thus prepared.

9. Take white arfenic in fine powder, and pure falt of tartar, of each fixty-four grains, put them into a Florence flalk, or other glafs veffel, along with half a pint of diftilled water, heat them flowly to boiling, till the ingredients are diffolved; when cold, add half an ounce of compound fpirit of lavender, and diftilled water fufficient to make up the whole quantity one pint, or rather fifteen ounces and a half troy-weight.

Of this folution, one ounce, apothecaries meafure, contains four grains of arfenic, or one dram, half a grain; and Dr. F. calculates each dram to be equivalent to eighty drops.

In preparing this liquid, the operator fhould be aware that the falt of tartar of the fhops, even the pureft, feldom makes a perfectly clear folution with water, but leaves a fmall earthy fediment, which no continuation of the boiling will diffolve. Inftead of this alkali, twice the weight of pure nitre has been employed, which promotes the folubility of the arfenic, and is perhaps fomewhat preferable to the falt of tartar. Thefe falts are not neceffary to the immediate folution of arfenic, but they prevent this metallic oxyd from feparating again from the water by long keeping.

The proportion of arfenic to water, in the folution, may be varied from the form above given; but as white arfenic requires eighty times its weight of cold water to remain diffolved, not lefs than this quantity fhould be employed, and the nitre or alkali fhould never be omitted, as it is of the utmoft importance for the practitioner to know precifely the dofe of arfenic which he prefcribes.

Dr. F. found that for the cure of intermittents it was of importance to give the arfenic in divided dofes as faft as the patients could bear it, without experiencing inconvenience from its poifonous effects. Strong adults could generally bear about ten drops of the folution (equivalent to one-fixteenth of a grain of arfenic) for a dofe, which he repeated twice, or, if convenient, thrice a day. By flow increafe, fome were able to bear as much as twenty drops for a dofe, and this courfe was continued for five days, when, if the fits of the intermittent were fufpended, the drops were interrupted for two or three days, and then refumed for three days longer to prevent a relapfe.

Infants could bear about two drops twice a day, and young or delicate perfons took the folution in intermediate dofes from two to ten or twelve drops.

The operation of this powerful remedy was truly furprifing in checking almoft immediately, and finally removing the paroxyfms of the moft obftinate intermittents, fome of which had refifted bark and other remedies for a confiderable time. In a few, however, it failed entirely; and in others the poifonous effects of the arfenic came on fo fpeedily that it could not be continued, and the cure was completed by bark and other tonics.

Every practitioner will be aware of the great caution neceffary in the exhibition of a remedy, which, though fafe in prudent hands, might induce the moft dangerous accidents if expofed to careleffnefs or ignorance. In moft of the fuccefsful cafes, the medicine removed the difeafe without producing any of the inconveniences attending its ufe in larger dofes; but when the arfenic began to fhew its poifonous effects, the fymptoms were, naufea, often accompanied with a flight griping and purging, fwellings of the foft integuments of the body, particularly the face, fometimes uneafinefs at the ftomach, and a flight eruption like the nettle-rafh; and, in a very few inftances, head-ach, fweat, and flight tremors. By attending to thefe ferious and very characteriftic warnings, and by the affiftance of gentle aperients, opiates, and other means which will readily fuggeft themfelves to the prudent phyfician, this terrible mineral may be enlifted into the fervice of the healing art, whilft its cheapnefs, infipidity, and great activity in a very fmall bulk, may fometimes render it preferable to the fafer drugs and barks, which opprefs the ftomach by their bulkinefs, and difguft by their naufeous flavour.

We may add that,

10. The arfeniat of potafh, defcribed in § 10. of the preceding article, has been employed in intermittents with the fame effect as the folution, and its ready folubility and uniformity of compofition may perhaps give it a claim to preference. The medium dofe of this falt may be a fifth of a grain three times a day.

Arfenic has been occafionally employed with confiderable fuccefs, when applied to the furface of the body in a variety of cutaneous complaints; and it might be adopted with more freedom, if it were not for the extreme danger to which any neglect of the warning fymptoms of poifoning might expofe the patient, a danger the more likely to be in chronic complaints often neglected, and not always fufficiently under medical infpection. Orpiment mixed with tar, with digeftive ointment, or other unctuous fubftances, has been found of eminent fervice in tinea capitis, a prefcription handed down to us from the ancients; but if the medical practitioner will venture on this hazardous, and not often neceffary remedy, he fhould never forget the much fuperior virulence and activity which the artificial orpiments and arfenical fulphurets poffefs over the natural. Orpiment and quicklime, boiled in water for a fhort time, form a liquor which, if often applied to the cuticle, caufes the hair to fall off; and the growth of it, when thus checked, is feldom renewed. Diofcorides. Plenk's Pharmacologia Chirurg. 1782. Fowler's Medical Reports on the Effects of Arfenic, 1786. Juftamond's Surgical Tracts, 1789. Pharm. Danica. Henry's Epitome of Chem. 1801, &c.

Battery

BATTERY, in *Electricity*, is a combination of coated surfaces of glass, so connected together, that they may be charged at once, and discharged by a common conductor. Mr. Gralath, a German electrician, was the first who contrived to increase the shock, by charging several phials at the same time. Dr. Franklin, after he had analyzed the Leyden phial, and found that it lost at one surface the electric fire which it received at the other, constructed a battery, consisting of eleven panes of large sash-glass, coated on each side, and connected in such a manner that the whole might be charged together, and with the same labour as one single pane; and by bringing all the giving sides into contact with one wire, and all the receiving sides with another, he contrived to unite the force of all the plates, and to discharge them at once. A more complete battery is described by Dr. Priestley, of which he says, that after long use he sees no reason for wishing the least alteration in any part of it. This battery (see *Plate* I. *Electricity*, *fig.* 1.) consists of 64 jars, each ten inches long, and $2\frac{1}{2}$ inches in diameter, coated within $1\frac{1}{2}$ inch of the top; and contains in the whole 32 square feet. The wire of each jar has a piece of very small wire twisted about the lower end of it, to touch the inside coating in several places; and it is put through a pretty large piece of cork, within the jar, to prevent any part of it from touching the side, which would tend to promote a spontaneous discharge. Each wire is turned round, so as to make a hole at the upper end; and through these holes a pretty thick brass rod with knobs passes, one rod serving for one row of the jars. The communication between these rods is made by laying over them all a thick chain. When part only of the battery is used, the chain is laid over as many rods as will furnish the required number of rows of jars. The bottom of the box, in which the jars stand, is covered with a plate of tin, and a bent wire touching the plate passes through the box, and appears on the outside. To this wire any conductor designed to communicate with the outside of the battery is fastened, as the small wire in the figure, and the discharge is made by bringing the brass knob to any of the knobs of the battery When a very great force is required, the quantity of coated surface may be increased, or two or more batteries may be used. Franklin's Exp. and Obs. ed. 1769. p. 28. Priestley's Hist. &c. of Electricity, ed. 1775. vol. ii. p. 99.

However complete the battery above described appeared to be at the time of its construction, later electricians have discovered many imperfections to which it was subject; of which the principal are those that result from the form and size of the jars, the substance of the glass, the height of the coating, and the connections within the battery. In consequence of these imperfections in its structure and contrivance, it is prevented from receiving more than about half the charge which it ought to receive in proportion to the quantity of its coated surface.

The most perfect batteries of modern construction, since that of Dr. Priestley, have been made in Holland for Teyler's museum at Haerlem, by Mr. Cuthbertson of Poland-street, London, then residing at Amsterdam. Of these batteries there are two, differing in their magnitude and mode of construction, but allowed to be equally perfect. The first was completed in the year 1784, and is composed of 135 jars in 9 boxes, each containing 15, which may be used separately or combined, as the nature of the experiment requires. Each box is a separate battery of itself; and the description of one box with a view of the figure, will be sufficient for explaining its construction and use. In *Plate* I. *Electricity*, *fig.* 2. is exhibited a perspective view of Teyler's first battery, with its parts arranged in proper order for receiving a charge from the electrical machine. Each box, as we have already observed, contains 15 jars; each jar is 11 inches high, and 6 inches in diameter, contracted at the mouth to 4 inches, and coated so as to contain about 140 square inches; and thus the whole battery will contain about 132 square feet of coated surface. Each box is divided into 15 partitions, 5 of which are in the length and 3 in the breadth; the height of the sides of the box being somewhat lower than the coating of the jars, as are also the partitions in which they stand. The lid of the box is made without hinges, for the convenience of releasing it from the box, that it may be removed while experiments are performed. It is taken off by lifting it upwards. The outside coatings of the jars are connected by means of cross wires passing under the bottom of each jar; and those on the inside by means of a brass frame, bearing 15 brass balls, fixed upon the frame above the centre of each jar. All these balls, excepting the four at the corners, have wires screwed to them and hanging downwards into the inside of each jar; but the wires of the four corner jars are screwed to a foot, which is cemented to the bottom of each in the inside. Upon these wires the whole frame rests, and is kept in its proper position. The four corner balls have holes, which receive the ends of the wires, and terminate at a proper height from the jars. By this contrivance the inside connecting frame may at any time be easily removed; and as this part of the machine is important, the construction of the said frame is shewn separated from the battery in *fig.* 3. It is according to the above construction that Mr. Cuthbertson forms his present batteries, excepting that he has increased the size of the jars, so as to make one battery contain about 17 square feet; and he engages to prove by experiment, that the batteries of his construction are far superior to any others. Teyler's second grand battery was finished by Mr. Cuthbertson in 1789. This is the largest and most complete battery that was ever made. The whole battery, standing in proper order for receiving a charge, is exhibited in *fig.* 4. It consists of 100 jars of the same shape with that of those already described, only that they are so enlarged in size, that each of them contains $5\frac{1}{4}$ square feet of coated surface, instead of 140 inches, and the whole battery contains 550 square feet of coating; and for conveniency, it is put into four separate cases, each containing 25 jars in the form of a square, 5 on each side. The boxes are lined with lead on the inside for forming the outside communication; each jar has a perpendicular stand resting upon its bottom, and supported from falling sideways by three stays on the inside. Upon the top is screwed a three inch brass globe, from which proceeds a brass tube about one inch in

diameter, to a large brafs globe, fupported by the middle jar at a proper height, fo as to keep the infide communication properly arranged. A view of the figure will fhew how the four are combined, fo as to charge and difcharge all the 100 jars at once.

Lieutenant colonel Haldane propofes the following method for meafuring the force of an electrical battery, during the time of its being charged.

Let the battery be infulated, and at a fmall diftance from it place an uninfulated electrical jar, and near the jar, one of Mr. Cuthbertfon's electrometers. The electrometer being adjufted according to the degree of force which is intended to be employed as a meafure of force to be communicated to the battery, connect the electrometer with the jar; make a metallic communication between the interior fide of the jar and the exterior fide of the battery, and connect the interior fide of the battery with the conductor of an electrical machine: then, by the operation of the electrical machine, the battery receives a quantity of the electrical fluid, and becomes charged. The fluid, which departs from the exterior fide of the battery, is received by the electrical jar, which alfo becomes charged; but this jar, being connected with the electrometer, explodes as foon as it acquires a force fufficient to put the electrometer into motion. The quantity of the electrical fluid which is received by this jar, between each of the explofions, is a meafure of the quantity of the fluid in the battery; and the number of explofions or difcharges of this jar fhews the number of meafures which the battery contains, and confequently the force which it is capable of exerting when difcharged.

For the author's demonftration of this method, and the illuftration of it by appropriate experiments, we muft refer to Nicholfon's Journal, vol. i. p. 156, &c.

Battery, *Galvanic*; the name ufually given to an apparatus for accumulating the electricity which is produced by the mutual agencies of certain metallic and carbonaceous fubftances, and peculiar fluids.

The firft inftrument of this kind was invented by the celebrated Volta of Pavia, in 1800, and various forms of it have been fince adopted by different philofophers.

The original battery, or the electrical pile, is compofed of plates of zinc, plates of filver, and pieces of pafteboard, of the fize of the plates, moiftened in a folution of falt in water: and arranged in the order of zinc, filver, pafteboard, zinc, filver, pafteboard, and fo on, till a feries fufficiently numerous is formed. On account of the expence of filver, copper has been lately generally fubftituted for it, with but little diminution of effect; and folutions of muriate of ammoniac, of nitrous acid, and of muriatic acid, have been employed inftead of the folution of common falt, with very great advantage as to the increafe of the power of the combination. In general any two metallic fubftances which are perfect conductors of electricity, may be ufed, provided the interpofed fluid is capable of oxidating at leaft one of them.

The powers of galvanic batteries appear to be very much connected with the chemical changes going on in them, and hence plates of one metal may be made to fupply the place of the two metals provided their different fides be expofed to different chemically acting fluids, as has been fhewn by the experiments of Mr. Davy. Thus copper, filver, and lead, all form efficient combinations when they are arranged with two different fets of pafteboard, one moiftened with diluted nitric acid, and the other with folution of hydrofulphuret of potafh; the order being metal, pafteboard moiftened with acid, pafteboard moiftened with hydrofulphuret, &c. In fuch a cafe, if the battery is required to be of confiderable permanency as to its effects, it is neceffary to feparate the pafteboard moiftened in the chemical agents from each other by a third fet of pafteboards, moiftened in common water.

In inftances when piles are erected perpendicularly either with two metals or with one metal, in confequence of the oxidation and the lofs of moifture from preffure and evaporation, the electrical action ufually ceafes after a few days; and in order to renew it, a fecond conftruction of the feries becomes neceffary. Several methods have been propofed for making inftruments more permanent in their operation than the pile, and more eafily rendered active; but the moft ingenious contrivance appears to be that of the trough, difcovered by Mr. Cruickfhank. It confifts of a box of baked wood, in which plates of copper and zinc, or of filver and zinc foldered together at their edges, are cemented in fuch a manner as to leave a number of water-tight cells, correfponding to the number of the feries: the arrangement becomes active when the cells are filled with the proper faline fluids; and it may at any time be eafily freed from oxide by the ufe of muriatic acid.

In the common apparatus of Volta, that part bounded by the moft oxidable metal, as, for inftance, the zinc, is found in a pofitive ftate, with regard to electricity, and the other part, as the copper, in a negative ftate; and when a communication is made between the two ends, by means of a conducting body, a conftant circulation of electricity is eftablifhed.

The electricity of the galvanic battery is capable of being partly transferred into the Leyden phial, and its effects, as has been fully fhewn by the experiments of Meffrs. Nicholfon, Carlifle, Woolafton, Van Marum, and Ritter, are fimilar to thofe of common electricity, in a low ftate of intenfity. It gives fhocks to living animal organs, and excites mufcular contractions in bodies for a confiderable time after death. It affumes the form of fire in paffing from one conducting body to another in its highly concentrated ftate; and it ignites fmall metallic wires or leaves, and caufes them to enter into combuftion. It fets fire to charcoal, fulphur, alcohol, and other inflammable bodies; and it rapidly decompounds water and various other fluids.

The intenfity of the electricity in Galvanic batteries is greater in proportion as the feries compofing them are more numerous: but the quantity of it depends upon the quantity of furface they contain. Hence equal numbers of large and fmall plates arranged in different batteries produce nearly the fame effects on the human body which is an imperfect conductor, and which can admit of the paffage only of a certain quantity of electricity of a low intenfity in a given time; but the large plates are in a determinate ratio, much more powerful in igniting the metals, and in affecting perfect conductors through which a large quantity of electricity, in any ftate of intenfity, eafily and inftantly paffes.

Many important philofophical difcoveries, which will be fully defcribed in the article Galvanism, have been already made, by means of the galvanic apparatus, in different parts of Europe; and a number of enlightened experimenters have been employed in inveftigating the principles on which its operation depends. The theory of it is, however, as yet obfcure, and the perfect developement of it will probably be connected with views more profound than any that have been as yet obtained of the nature and agencies of electricity, and its relations to chemical changes. See Phil. Tranf. for 1800 and 1801. Nicholfon's Journal, vol. iv. and v., and vol. i. new feries. Journals of the Royal Inft. vol. i. Tilloch's Phil. Mag. vol. x. xi. and xii. Annalen der phyfik. Journal de phyfique. Annales de Chimie.

Benzoin

Benzoin, *Benjamin Gum*, and *Benzoic Acid*, in *Chemistry* and *Pharmacy*.

The gum benzöin or benzöe, by some called also *Asa Dulcis*, is a very fragrant resin, procured from a large tree found in many parts of the East Indies, Sumatra, Arabia, Persia, &c. See Styrax *Benzöe*.

The resin is brought in large brittle masses of a light yellow, interspersed with white nodules, which last are considered as the finest, and called by some *Benzöe Amygdaloides*. The smell of Benzoin is extremely fragrant, especially when rubbed or heated: it has scarcely any taste, except previously dissolved in spirit of wine, which it does with ease, into a yellowish tincture. On adding water to this tincture, the resin again separates into a white pulverulent mass, which has received the singular name of *Lac Virginale*, and also *Magistery of Benzoin*. When gently dried, it forms a white powder, formerly in great request as a cosmetic. It is at least innocent, and its scent is one of the most agreeable. But the most striking ingredient of this resin is the

Benzoic Acid, which is of sufficient importance to require

Benzoic Acid, which is of sufficient importance to require being described more at large. If benzoin is gently heated a little above the degree of boiling water, it melts into an adhesive mass, and at the same time sends out a very copious, dense, white fume, of an extremely fragrant, diffusive, penetrating smell, and so acrid as irresistibly to excite coughing and tears in those who are in any degree exposed to it. This fume soon condenses on the first cool body, and then appears in the form of very beautiful spicular crystals, which gradually collect into a bulky feathery mass, extremely light, and of remarkable elegance and lustre. This crystalline mass is the benzoic acid, and its acid property is proved by reddening litmus, neutralizing alkalies, and forming with them peculiar salts; in modern chemical nomenclature called *Benzoats*. After the greater part of the acid has risen by sublimation, or before it, if the heat be at all increased, a thin yellowish oil rises slightly empyreumatic, but strongly imbued with the fragrance of the resin. On further heating, an acidulous liquor comes over, together with a thick butyraceous matter; still, however, containing some of the crystallizable acid, which is not totally expelled till the end of the process.

This acid is readily soluble in alcohol, and in hot water, but so sparingly in cold water, that a hot saturated solution will deposit in crystals almost its saline contents by cooling.

Several methods have been devised for obtaining the benzoic acid. The oldest and most expeditious is by simple sublimation. To perform any quantities of it, put benzoin in an earthen pipkin; apply to the vessel a large cone of clean white paper, pasted down to the edges of the pot, and set it over an extremely slow charcoal, or other fire, just sufficient to melt the benzoin. The acid will rise and crystallize upon the inside of the paper cone. However, as in this method the vapour has hardly room to concrete, instead of the paper cone, another vessel inverted over that which contains the resin, and with a small hole drilled through its bottom, may be substituted; and when full, it may be gently shaken, to detach the acid, and again applied. From nine to twelve drachms may be thus obtained from sixteen ounces of benzoin. The remaining resin is still very aromatic, and should not be lost.

Another method has been recommended by Scheele, who in his excellent practical observations upon this salt, has treated it with that precision and ingenuity which so eminently distinguish this chemist in every subject, of greater or less importance and difficulty, which he has illustrated by his labours.

He observes, that besides sublimation, the acid may be extracted by lixiviation, and with the advantage of obtaining it free from any admixture of oil, which is apt to impair its whiteness and lustre. If benzoin is boiled with water, and the solution strained while hot, and suffered to cool, most of the acid taken up by the hot water deposits when cold, and may then be collected pure. This method, however, is imperfect; for as the water does not mix with and divide the gum, this last soon softens, and sinks down, closely adhering to the bottom of the vessel, and does not allow of the water easily to penetrate it. Hence the solution takes place only at the surface of the benzoin.

The same chemist boiled powdered chalk and benzoin in water, and filtrated the liquor. No crystals were now deposited on cooling, for the acid had dissolved part of the chalk into a benzoat of lime, which, being very soluble, remained in the liquor. But on adding some drops of vitriolic acid, the benzoic acid was again separated from the lime, and fell to the bottom in a powdery form. Substituting alkali for the chalk, the same effect took place, and the benzoic acid, as before, was precipitated by the vitriolic. But this method was still attended with the inconvenience of the benzoin concreting together, which floated on the surface during the boiling. But on substituting quick lime this inconvenience was avoided; and it is therefore in the following method that the benzoic acid may be procured the most copiously and the purest. Upon four ounces of unslacked lime pour twelve ounces of water, and after the ebullition is over, add six pounds more of water; then put a pound of benzoin, finely powdered, into a tin pan; pour on it at first about six ounces of the above lime water; mix them well together, and then successively the rest of the lime water. By this method the resin will be prevented from running together into one mass. Boil the mixture for half an hour, with constant stirring, then let it stand, and pour off the clear liquor. On the remainder in the pan, pour more lime water, and proceed as before, adding the clear liquor to that first obtained, and also filter the residue, to exhaust the liquor, which is now a weak solution of benzoic acid, with the lime of the lime water. Boil down this liquor (which is of a light yellow) to two pounds, and strain. When cold, add to the liquor muriatic acid gradually, which will produce a white crystalline deposition, and continue to add the acid till the liquor is supersaturated, and tastes sourish. The stronger acid thus unites with the lime, and the benzoic acid, now free, being of itself scarcely soluble in cold water, falls down as a white coagulum, which should be washed with more cold water, and gently dried. To give it a crystalline appearance, dissolve it in boiling water, filter it through a cloth, and by cooling it will separate in the form of spicular crystals, but with some loss of the acid.

The above process of Scheele's may however be a little shortened, if the lime in substance be mixed with the lime water, previous to the addition of the benzoin; for by this method the solution may be at once made more concentrated, and less of the liquid will suffice, so that much of the evaporation will be saved. Any of the stronger acids will displace the benzoic from lime, but the muriatic is the most convenient.

Scheele obtained from 12 to 14 drachms of the concrete acid from a pound of benzoin by this process.

The benzoic acid, when pure, is quite white; for if yellow, it is mixed with a small portion of the oil of the resin. Though crystallized, it is considerably elastic, and difficult to be reduced to powder. Its taste is sharp, pungent, and acidulous. It reddens tincture of litmus. When cold, it is without smell, but on applying heat it sends forth the peculiar grateful odour by which it is characterized. Heated by itself, it chiefly sublimes, but a part is decomposed, giving an acid phlegm, much oil, and carburetted hydrogen gas. It is not alterable in the air, and does not evaporate by keeping in a moderate temperature. Cold water dissolves only about $\frac{1}{300}$ of its weight, but boiling water $\frac{1}{20}$; and hence the copious crystallization from a hot water solution. It unites readily to most of the alkalies and earths forming benzoats, the properties of which have been but little examined.

The benzoat of lime is almost the only salt of this kind found native. It is contained in the urine of some animals, particularly the herbivorous quadrupeds, and is ascertained by adding to this secretion some muriatic acid, by which the benzoic acid is made perceptible.

With potash this acid forms a readily crystallizable salt, decomposable, like the rest of the benzoats, by a strong acid.

Most of the metallic oxyds are dissolved by this acid, but not the pure metals.

Mr. Hermbstadt, in a series of experiments on the action of nitrous acid on the benzoic, found that the latter regularly assumed in the process a smell like that of water distilled over

bitter almonds, but on the whole, this acid is but with difficulty altered in its nature by the nitrous. Diſtilling the nitro-benzoic acid with pure alcohol, he obtained ethereal liquor, part of which was nitrous ether, but the remainder appeared, by the ſmell of almonds, to be a dulcified, or ethereal benzoic acid. But theſe experiments require to be repeated with accuracy, as the powerful operation of the nitric acid on vegetable matter, though highly inſtructive, is often not a little embarraſſing.

Several other ſubſtances, beſides the reſin of benzoin, contain more or leſs of this acid. The balſam of Peru, and of Styrax, appear to owe to this acid much of their fragrant ſmell. Ambergris, vanilla, and ſome of the aromatic barks, and even urine, contain a ſmall quantity of it. When uncombined with an alkaline or earthy baſe, it is generally known by a pungent fragrant ſmell, and denſe white ſmoke, on applying a heatleſs than is neceſſary to burn or decompoſe the ſubſtance with which it is united. When kept down by an alkali or an earth (as in the caſe of urine), it is ſeparated by a ſtrong acid. It has been ſuppoſed, with probability, that the fragrant ſcent is not proper to the acid, but is owing to the preſence of a portion of reſin or eſſential oil, combined with it ſo intimately as to be inſeparable by any means hitherto known, without entire decompoſitions of the acid; and hence too may be explained the very weak affinity of this acid for all baſes, which is generally ſuperior to no acid but the carbonic.

Gum benzoin is almoſt diſuſed in medicine, though ſtill retained in a few preparations of the London and Edinburgh pharmacopœias. The compound tincture *Tinctura Benzöes Compoſita*, formerly *Balſamum Traumaticum*, contains gum benzoin, balſam of Tolu, and aloes; and the benzoic acid enters into the Edinburgh *Tinctura Opii Ammoniata*, and in ſome other compounds of foreign diſpenſaries.

The fragrance of this reſin has cauſed it to be uſed in fumigations of various kinds. Where the object is merely to produce a penetrating agreeable ſcent, it may be of conſiderable uſe; but as a *corrective* of foul or contagious air, its powers are very ſmall, by no means comparable to thoſe of the mineral acid vapours, while the irritation which it gives to the lungs is more intolerable. Scheele's Eſſays. Fourcroy. Hermbſtadt in J. Phyſ. tom. 34, &c.

Bevel

BEVEL, in *Masonry*, and among *Joiners*, a kind of square, one leg whereof is frequently straight, and the other crooked, according to the sweep of an arch or vault; being also moveable on a point, or centre, so that it may be set to any angle. The make and use of the bevel are pretty much the same as those of the common square or mitre, except that these latter are fixed; the first at an angle of ninety degrees, and the second at forty-five; whereas the bevel, being moveable, may, in some measure, supply the office of both, and yet, which it is chiefly intended for, supply the deficiencies of both, serving to set off or transfer angles, either greater or less than ninety or forty-five degrees.

Bricklayers have also a bevel, by which they cut the under sides of the bricks of arches straight or circular, to such oblique angles as the arches require, and also for other uses.

Bevel, *Graduated*, is that which has about the centre of one of its arms a semicircle graven, and divided into 180 degrees, whose diameter stands square with the sides of the same arm; so that the end of the other arm, being divided at right angles, almost to the centre, shews by its motion the number of degrees contained in the angle to be measured. This is also called *recipiangle*, and *pantameter*.

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The *simple Bevel* (see *Plate* II. *Geometry*, *fig*. 35.) consists of two rulers moveable on a common centre, like a carpenter's rule, with a contrivance to keep them fixed, at any required angle. The centre C must move on a very fine axis, so as to lie in a line with the fiducial edges CB, CD of the rulers, and project as little as possible before them. The fiducial edges of the legs represent the sides of any given angle, and their intersection or centre C, its angular point. A pin, fixed in the lower ruler, and passing through a semicircular groove in the upper, serves, by a nut A, which screws upon it, to fix the rulers, or legs, when they are placed at the desired angle.

The use of this instrument may be illustrated in the following examples:

1. Let 3 points, A, B, C, be in the circumference of a circle, which is too large to be described by a pair of compasses; and let it be required to find any other number of points in the same circumference. Bring the centre of the bevel to B (*fig*. 36.), the middle point of the 3 given ones A, B, and C, and holding it there, open or shut the instrument till the fiducial edges of the legs lie upon the other two points, and fix them there by means of the screw A (*fig*. 35.): this operation is called *setting* the bevel to the given points. Then removing the centre of the bevel to any part between B and A or C, the legs being at the same time kept upon A and C, that centre will describe, or be always found in, the arc which passes through the given points, and will thus ascertain as many others as may be required between the limits of A and C. In order to find points without those limits, proceed in the following manner: the bevel being *set*, bring the centre to C, and mark the distance CB upon the left leg; remove the centre to B, and mark the distance BA upon the same leg; then placing the centre on A, bring the right leg upon B, and the first mark will fall upon *a*, a point in the circumference of the circle, passing through A, B, and C, whose distance from A is equal to the distance BC. Removing the centre of the bevel to the point *a* last found, and bringing the right leg to A, the second mark will find another point *a*″ in the same circumference, whose distance *aa*″ is equal to AB. By proceeding in this manner, any number of points may be found, whose distances on the circumference are alternately BC and BA. In the same manner, by making similar marks on the right leg, points on the other side, as at *c*′ and *c*″ are found, whose distances C*c*′, *c*′*c*″, are equal to BA, BC respectively. Intermediate points between any of the above are given by the bevel in the same manner with those between the original points.

2. Three points, A, B, and C, being given, to draw a line from any one of them, tending to the centre of the circle, which passes through them all. Set the bevel to the three given points A, B, and C (*fig*. 37.); lay the centre on A, and the right leg to the point C, and the other leg will give the tangent AG′. Draw AD perpendicular to AG′ for the line required. For BAE being = BCA, the angle EAC is the supplement to the angle ABC, or that to which the bevel is set; hence, when one leg is applied to C, and the centre brought to A, the direction of the other leg must be in that of the tangent G′E.

3. Three points being given as before, let it be required to draw from a fourth given point D, a line tending to the centre of a circle passing through the first three points. On D (*fig*. 38.), with the radius DA describe an arc AK; set the bevel to the three given points A, B, and C, and bring its centre, always keeping the legs on A and C, to fall on the arc AK, as at H; on A and H severally, with any convenient radius, strike two arcs, crossing each other at I; and the required line D*d* will pass through the points I and D. For a line drawn from A to H will be a common chord to the circles AHK and ABC; and the line ID bisecting it at right angles, must pass through both their centres.

4. Three points being given as before, together with a fourth point, to find two other points, such, that a circle passing through them and the fourth point, shall be concentric to that passing through three given points. Draw A*c* and C*c* tending to the centre, by a former problem; set the bevel to the three given points A, B, and C; bring the centre of the bevel to D, and move it upon that point till its legs cut off equal parts AN, CQ, of the lines A*a* and C*c*; and N and Q will be the points required. For, supposing lines drawn from A to C, and from N to Q, the segments ABC and NDQ will be similar ones; and consequently, the angles contained in them will be equal.

5. Two lines tending to a distant point being given, and also a point in one of them; to find two other points (one of which must be in the other given line), such, that a circle passing through these three points may have its centre at the point of intersection of the given lines. Draw EH (*fig*. 39.) at right angles to AB, and make FH = FE; set the bevel to the angle GDO, and keeping its legs on the points H and E, bring its centre to the line AB, which will give the point I.

An improved bevel is exhibited in *fig*. 40. by which the arcs of circles of any radius, without the limits attainable by a common pair of compasses, may be described. It consists of a ruler AB, composed of two pieces rivetted together near C, the centre or axis, and of a triangular part CFED. The axis is a hollow socket fixed to the triangular part, about which another socket, fixed to the arm CB of the ruler AB, turns. These sockets are open in the front for part of their length upwards, as represented in the section at I, which shews the point of a tracer, or pin, fitted for sliding in the socket. The triangular part is furnished with a graduated arc DE, by which and the vernier at B, the angle D*c*B may be determined to a minute. In this arc is a groove, by means of which, as well as by the nut and screw at B, or some similar contrivance, the ruler AB may be fixed in any required position. A scale of radii is put on the arm CB, by which the instrument may be set to describe arcs of given circles, not less than 20 inches in diameter. In order to set the instrument to any given radius, the number expressing it in inches on CB, is brought to cut a fine line drawn on CD, parallel and near to the fiducial edge of it, and the arms are fastened in that position by the screw at B. Two heavy pieces of lead or brass G, G, made in form of the sector of a circle, the angular parts being of steel, and wrought to a true upright edge, as shewn at H, are used with this instrument, whose arms are made to bear against those edges when the arcs are drawn. The under sides of these sectors are furnished with fine short points to prevent them from sliding. The fiducial edges of the arms CA and CD, are each divided from the centre C into 200 equal parts. This instrument might be furnished with small castors, like the pentagraph; but little buttons, fixed on its under side, near A, E, and D, will enable it to slide with sufficient ease.

The use of this instrument may be exemplified in the following problems:

1. To describe an arc, which shall pass through three given points.—Place the sectors G, G′, with their angular edges over the two extreme points; apply the arms of the bevel to them, and bring at the same time its centre C, that is, the point of the tracer, or pen, put into the socket, to the

arms constantly bearing against the two sectors, till it comes to the right-hand sector, by which the required arc will be described by the motion of its centre C. If the arc be wanted in some part of the drawing *without* the given points, find by case 1. under *simple bevel*, other points in those parts where the arc is required; and thus a given arc may be lengthened as far as is necessary.

2. To describe an arc of a given radius, not less than 10 inches.—Fix the arm C B so that the part of its edge, corresponding to the given radius, always reckoned in inches, may lie over the fine line drawn on C D for that purpose; bring the centre to the point through which the arc is required to pass, and dispose the bevel in the direction in which it is intended to be drawn; place the sectors G, G, exactly to the divisions 100 in each arm, and strike the arc as above described.

3. The bevel being set to strike arcs of a given radius, as in the last instance, let it be required to draw other arcs, whose radii shall have a given proportion to that of the first arc. Suppose the bevel to be set for describing arcs of 50 inches radius, and it be required to draw arcs of 60 inches radius, with the bevel so set. Say, as 50 is to 60, so is the constant number 100 to 120, the number on the arms C A and C D, to which the sectors must be placed, in order to describe arcs of 60 inches radius. When it is said that the bevel is set to draw arcs of a particular radius, it is always understood that the sectors G, G, are to be placed at N° 100 on C A and C D, when those arcs are drawn.

4. An arc A C B (*fig.* 41.) being given, let it be required to draw other arcs concentric to it, which shall pass through given points, e. g. P. Through the extremities A and B of the given arc, draw lines A *p*, B *p*, tending to its centre, by case 3. under *simple bevel*. Take the nearest distance of the given point P from the arc, and set it from A to P, and from B to P. Hold the centre of the bevel on C, any point near the middle of the given arc, and bring its arms to pass through A and B at the same time, and fix them there. Place the sectors to the points P and P, and with the bevel, set as before directed, draw an arc, which will pass through P the given point, and be concentric to the given arc A C B.

5. Through a given point A (*fig.* 42.) in the given line, to strike an arc of a given radius, and whose centre shall lie in that line, produced if necessary. Set the bevel to the given radius, by case 2. Through A, at right angles to A B, draw C D; lay the centre of the bevel, set as above, on A, and the arm C A on the line A C, and draw a line A E along the edge C D of the other arm. Divide the angle D A E into two equal parts by the line A F, and place the bevel so that, its centre being at A, the arm C D shall lie on A F; while in this situation, place the sectors at N° 100 in each arm, and then strike the arc.

6. An arc being given, to find the length of its radius. —Place the centre of the bevel on the middle of the arc, and open or shut the arms till N° 100 on C A and C D, fall upon the arc on each side of the centre; the radius will be found on C B (in inches) at that point of it, where it is cut by the line drawn on C D. If the extent of the arc be not equal to that between the two Nos. 100, make use of the N° 50, in which case the radius found on C B, will be double of that sought; or the arc may be lengthened by prob. 1. till it be of a sufficient extent to admit the two Nos. 100. Adams's Geometrical and Graphical Essays, by Jones, 1797.

Birmingham

BIRMINGHAM, is juſtly eſteemed the greateſt manufacturing town in England, and we may ſafely aſſert, that in the quantity, variety, elegance, and utility of its manufactured articles, it ſurpaſſes any town in Europe. To enable the ſtranger and foreigner to appreciate the general character of this place, with its various ſubordinate features, we will endeavour to depict them to the fancy, in a conciſe and perſpicuous narrative. Its diſtinguiſhing characteriſtic is appropriately diſplayed in the following lines by Mr. Jago, in his poem of "Edge-hill."

"'Tis noiſe, and hurry all.—the throng'd ſtreet,
The cloſe pil'd warehouſe, and the buſy ſhop.
With nimble ſtroke the tinkling hammers move;
While ſlow and weighty the vaſt ſledge deſcends,
In ſolemn baſe reſponſive, or apart,
Or ſocially conjoined in tuneful peal.—
How the coarſe metal brightens into fame,
Shap'd by their plaſtic hands! what ornament!
What various uſe!—Nor this alone thy praiſe,
Thine too of graceful form, the letter'd type!
The friend of learning, and the poet's pride."

The etymology of the name of this town is not readily attained, as it has been written Brumwychehām, Bromwycham, and various other ways; indeed, in common converſation, it is frequently pronounced Bromidgham. The town lies near the centre of the iſland, in the north-weſtern extremity of the county of Warwick. It is in the dioceſe of Lichfield and Coventry, in the deanery of Arden, and in the hundred of Hemlingford. The ſuperficial contents of the pariſh are 2864 acres. In 1800 here were 16,403 houſes, 1875 of which were uninhabited. The whole population was 73,670, of whom 34,716 were males, and 38,954 were females.

In the ſcale of national importance, Birmingham bears an exalted ſituation; without recurring to its ancient hiſtory, the modern inhabitants have, by laudable induſtry, raiſed it perhaps to the acme of manufacturing and commercial fame. The ſagacious and elegant Burke emphatically pronounces Birmingham the "Toy Shop of Europe." This deſignation muſt not, however, be taken in its literal ſenſe, as the articles of utility made in this town far exceed thoſe intended only for ſhew and ornament. Many of our cities are attractive for their venerable ruins and grand cathedrals, but of thoſe Birmingham is deſtitute. The traveller, who delights in ſeeing the human race profitably employed to their own, and their country's advantage, will diſregard the ſmoke which ſometimes envelopes the town, and diſcern through the veil the bright beams of induſtry enlightening vaſt piles of riches: juſtice, however, will compel him to acknowledge, that profligacy has contrived to inſinuate itſelf within too many dwellings of the labouring claſſes, producing idleneſs, diſcontent, drunkenneſs, and riots, of which ſeveral inſtances might be cited, excluſive of that grand convulſion which attended the commencement of that revolution in France, which in its conſequences has ſo ſeverely oppreſſed this, and almoſt every other nation. The Ikenild-ſtreet, one of the great Roman military roads, comes within a mile of Birmingham, and in Sutton park and Coldfield, four miles from the town, it remains nearly as perfect as if juſt completed; one of the principal evidences of the antiquity of Birmingham is, that it is contiguous to two Roman roads, the Ikenild, and Shirley ſtreets.

The family of Birmingham were lords of this manor till 1537, at which period it is ſaid to have been obtained by the duke of Northumberland, through the ſucceſs of a deep-planned ſcheme. Having endeavoured in vain to purchaſe it, he contrived to make Edward Birmingham appear as an accomplice in a highway robbery, and offered him his intereſt to ſave a forfeited life, on condition of ſelling him the manor. The manor-houſe, which is now called the mote, ſtill remains, though the ſite has been converted into a manufactory, and an apartment is ſhewn, where the ancient lords held their court-leets.

The pariſh of Birmingham is ſmaller than any in its neighbourhood. Mr. Hutton obſerves, that when Alfred founded a town, he allotted a much ſmaller ſpace of land to it, than when he portioned a village, obviouſly intending the former for trade and commerce, and the latter for agriculture; this circumſtance ſeems to prove that Alfred *found* Birmingham a *town*. "The buildings occupy the ſouth-eaſt part of the pariſh, which, with their appendages, are about 800 acres. This part being inſufficient for the extraordinary increaſe of the inhabitants, ſhe has of late extended her buildings along the Bromſgrove road, near the boundaries of Edgbaſton, and on the other ſide planted ſome of her ſtreets in the pariſh of Aſton."

"The ſituation is elevated, and the ſoil one ſolid maſs of dry, reddiſh ſand, through which the water deſcends freely, thus making even the cellars comfortable habitations;" the ſame author adds facetiouſly, that though metals of various ſorts are found in great plenty above the ſurface, we know of nothing below except ſand, gravel, ſtone, and water. All the riches of the place, like thoſe of an empiric in laced clothes, appear on the outſide. "There is not any natural river in the pariſh, but in the lower parts of the town are two excellent ſprings of ſoft water, ſuitable for moſt purpoſes, one at the top of Digbeth, the other Lady well; and at the latter place are ſeven of the moſt complete baths in the kingdom. They coſt 2000 *l.* in erecting, and are ever ready for the accommodation of hot or cold bathing, for immerſion or amuſement, with conveniency for ſweating. That appropriated to ſwimming is 18 yards by 36, ſituate in the centre of a garden, in which are 24 private undreſſing houſes, and the whole ſurrounded by a wall ten feet high."

Mr. Hutton mentions ſeveral inſtances of longevity, which ſeem to demonſtrate either that the air is too pure to be rendered unwholeſome by the ſmoke of the town, or that

ſmoke

ſmoke and ſteam are not ſo prejudicial to health as have been imagined: his inſtances are one perſon aged 100, a ſecond 103, a third 104, and a fourth 107, four upwards of 90, and 13 upwards of 80.

Birmingham is not a place a gentleman would chuſe to make a reſidence. Its continual noiſe and ſmoke prevent it from being deſirable in that reſpect.

Many ancient families who once flouriſhed at and near Birmingham, are mentioned by Mr. Hutton to have fallen into irretrievable decay; one inſtance is worth tranſcribing. "We have among us a family of the name of Middlemore, of great antiquity, deducible from the conqueſt; who held the chief poſſeſſions, and the chief offices in the county, and who matched into the firſt families in the kingdom, but fell with the intereſt of Charles I., and are now in that low ebb of fortune, that I have frequently, with a gloomy pleaſure, relieved them at the common charity board of the town."

It appears upon record, that in 1251, William de Birmingham, lord of the manor, procured an additional charter from Edward III. reviving ſome decayed privileges, and granting others; among the laſt was that of the Whitſuntide fair, to begin on the eve of Holy Thurſday, and to continue for four days. At the alteration of the ſtyle in 1752, it was prudently changed to the Thurſday in Whitſun week, that leſs time might be loſt to the injury of the manufacturers and their workmen. The ſame perſon alſo procured another fair, to begin on the eve of St. Michael, (which is commonly called the Onion fair, on account of the great quantity of onions ſold at the time) both of which are at this day in great repute. The horſe fair, which formerly was kept in Edgbaſton-ſtreet, was, in 1777, removed to Brick-kiln-lane; and that for beaſts, which uſed to be in the High-ſtreet, into Dale end, in 1769.

Near Birmingham, on the London road, is Camp-hill, where the army of prince Rupert were encamped, during the ſiege in 1643. The inhabitants are accuſed of diſloyalty by lord Clarendon, for ſeizing the carriages which contained the royal plate and furniture. The prince, with 2000 men, had been commanded by the king to open a communication between Oxford and York, but the hardy and imprudent inhabitants of this town dared to oppoſe this force, with only a company of foot, and a troop of horſe. Though they had thrown up ſome ſlight works, and blockaded the ſtreets, yet the king's army forced through theſe trifling obſtructions, and entered the town ſword in hand. The earl of Denbigh, a royaliſt, was killed in this affair, as was a clergyman who acted as governor for the parliament, and who refuſed quarter. Birmingham had a narrow eſcape from deſtruction, for the exaſperated commander ordered the place to be burnt, but ſome favourable circumſtance confined the conflagration to a few houſes in Bull-ſtreet.

The plague of 1665, was imported into the town in a box of cloaths brought to the White Hart inn. Hence the fatal poiſon inſinuated itſelf through the ſtreets and houſes, deſtroying great numbers of the inhabitants, whoſe bodies ſoon filled the church-yard, and alſo an acre of land at Ladywood green, which was afterwards called the Peſt-ground.

Although ſome degree of eminence attached to Birmingham previouſly to the reign of Charles II., yet it is from that period that its rapid increaſe muſt be dated. Building leaſes then became common, and numbers of houſes aroſe to accommodate the increaſing population which aſſembled, in conſequence of the cultivation of the mechanical arts.

About the year 1700, the number of ſtreets in Birmingham was only 30, but now there are nearly 250; beſides, ſeveral of the oldeſt are conſiderably improved and augmented. This will, in ſome meaſure, aſſiſt the imagination in comprehending the amazing increaſe of the town in ſize, wealth, and manufactures, during that time; and it is no preſumption to ſuppoſe, that it has not yet arrived at its zenith; one inſtance of increaſe will be ſufficient to point out the general improvement. Between the roads to Wolverhampton and Dudley, there were only three houſes March 14, 1779. By that day twelve months they increaſed to 55, and March 14, 1781, there were 144. The ſame day in 1791, there was an addition of 833.

Thomas Sherlock, biſhop of London, purchaſed of the ladies of the manor in 1730, land worth 400l. per annum; in 1758, the income was doubled. He always refuſed to let it on building leaſes, alledging, that his ſucceſſor would be compelled to remove the rubbiſh at the expiration of the terms; ſir Thomas Gooch, who held the land after the above prelate, procured an act about 1766, for ſetting aſide the prohibitory clauſes of the biſhop's will; immediately let the ground, and improved the rents to 2400l. per annum; it appears from the books of the poor-rates, that leſs than 5000 houſes pay the parochial dues, and more than 8000 houſes are exempt; this fact denotes the prevailing deſcription of population.

Manufactures, &c. The extraordinary increaſe in the ſize, population, and proſperity of Birmingham, ariſes principally from its proximity to the coal mines, from the nature of the ſoil, from its canals, from the ſucceſsful exertions of a few individuals in ſome manufacturing ſpeculations, and from its being exempt from borough, and corporate laws and reſtrictions. To inveſtigate and detail the whole of theſe cauſes, with their effects, would occupy more ſpace than we can conſiſtently appropriate. The moſt prominent characteriſtics, however, ſhall be narrated. To the late John Taylor, eſq. a man of great induſtry and ingenuity, the public are indebted for the gilt button, the japanned and gilt ſnuff-box, with the numerous claſs of enamels; alſo the painted ſnuff-box, at which employ, one ſervant earned 3l. 10s. per week, by painting them at a farthing each. In his ſhops were weekly manufactured buttons to the amount of 800l. excluſive of other valuable productions, and eighty guineas have been given him for a ſingle toy made at his ſhop. He died in 1775, at the age of 64, after acquiring a fortune of 200,000l. His ſon is now partner in one of the largeſt provincial banking houſes in England.

The greateſt and moſt noted manufactory of this place, and perhaps in Europe, is that at Soho, about two miles from Birmingham. This is the property of Meſſrs. Boulton and Watt, who have advanced certain pieces of mechaniſm and productions of art to a ſtate of excellence, that have excited the aſtoniſhment and admiration of nations. The large warehouſes, work-ſhops, and the elegant manſion of the former gentleman, cover the declivities of a hill, which a few years back was a barren heath, tenanted only by rabbits, and a warrener's hut; now this once deſolate ſcene is converted into an emporium of arts and beauties. Such are the wonderful powers of human ingenuity and induſtry. In 1757, this ſpot, with ſome contiguous land, was leaſed for 99 years, to Meſſrs Ruſton and Evans, who erected a houſe and a mill for rolling metal, &c. At Lady day 1762, Mr. Boulton bought the whole, and removing to it ſoon afterwards from Birmingham, commenced the preſent extenſive premiſes, which were nearly completed in 1765, at an expence of 9000l. He now admitted a partner, Mr. Fothergill, into the concern, and

established an extensive correspondence throughout Europe. To obtain and support a reputation, every encouragement was afforded to men of genius in drawing, modelling, and other branches of the arts. An imitation of or molu in vases, tripods, and candelabras, was adopted, accompanied by so much skill and elegance, that universal approbation followed; this led to the manufacture of wrought silver, and an application was made to parliament in 1773, for an assay office, to be established at Birmingham. The polygraphic art had its origin at Soho. This method of copying pictures in oil, by a mechanical process, was conducted by F. Eginton, who has since executed a great number of fine specimens of painting. or staining of glass. The encaustic mode of staining glass, or fixing the vivid and fine graduating colours upon that transparent material, was supposed to be lost, but it has been revived and brought to great perfection by this gentleman. Since 1784, he has executed several large windows for various cathedrals, churches, and gentlemen's mansions. (See GLASS PAINTING.) Among the various machines, &c. invented and constructed at Soho, there is one entitled to distinguished notice for its great national utility and importance. This is the *steam engine*, which has acquired extraordinary force and improvements by Mr. James Watt, one of the proprietors of the Soho firm. To him the scientific world is much indebted for various other inventions and improvements in mechanics. With a vigorous comprehensiveness of mind, he embraces every mathematical and mechanical subject from the simplest to the most complex and profound. He procured a patent for the steam engine in 1768, and seven years afterwards, entering into partnership with Mr. Boulton, began to construct those machines at Soho. Since that period, they have been generally adopted in the mines and manufactories all over the kingdom. (See STEAM ENGINE) The following list of curious and useful articles are manufactured at these works, which, when fully employed, give support to upwards of 600 labourers. Buttons of all kinds; polished steel, and jettina steel-toys; polished steel watch chains; patent cork-screws, &c. Buckles and lachets of all sorts; plated and silver goods for the dining and tea-table, side-board, &c.; medals and coins of various sizes and metals. The late beautiful new coinage of copper, and also the re-stamped dollars; all come from the Soho mint. The coining mill or engine first erected here in 1783, has been much improved since that period, and is now adapted to work eight machines at once, each of which will strike from 70 to 84 pieces per minute, the size of a guinea; or between 4,000 and 5,000 per hour. Thus the eight machines will work between 30,000 and 40,000 coins in one hour. These machines are operated on by the steam-engine, and perform the following processes: 1st. rolling the masses of copper into sheets; 2nd, fine rolling of the same cold, through cylindrical steel rollers; 3rd, clipping the blank pieces of copper for the die; 4th, shaking the coin in bags; 5th, striking both sides of the coin, and milling it, at the same time displacing it, and placing another for the same operation. To its other properties, this ingenious machine adds the almost magical one of preventing fraud, by keeping an accurate account of every coin which passes through it. Dr. Darwin has described this singular apparatus in the following apposite poetical lines:

——"Now his hard hands on Mona's rested crest,
Bosom'd in rocks, her azure ores arrest;
With iron lips his rapid rollers seize
The lengthened bars in their expansive squeeze;
Descending screws with pond'rous fly-wheels wound
The tawny plates, the new medallion's round;
Hard dies of steel, the cupreous circles cramp,
And with quick fall, his massy hammers stamp.
The harp, the lily, and the lion join,
And George and Britain guard the splendid coin."

Rolled metals of all kinds of mixtures, are prepared here; besides pneumatical apparatus, large and portable; also copying machines, and in short, almost every sort of article for use or ornament.

Besides the manufactories already named, Birmingham contains several others, which are entitled to our consideration; and although we cannot allow space for particulars, yet we must not pass them altogether unnoticed.

Messrs. Richards's in High-street, is styled the toy-shop of Birmingham; the elegance and variety of the articles are not to be equalled, with the exception of the show-room at Soho. Mr. Clay's japan manufactory is not less celebrated, particularly when it is considered that the japan is fixed on common brown paper. To those may be added Clarke and Ashmore's manufactory of whips. Gill's gun, bayonet, and sword manufactory, supposed to be one of the best in the world; and Galton's for sporting guns. Previous to the reign of William III. guns were mostly imported from Holland; but that monarch having once expressed some regret at this circumstance, and deplored the necessity of sending abroad for the article, Sir Richard Newdigate, M.P. for Warwickshire, being present, assured the king that his constituents would undertake to supply the demands of government. An order was given, and being readily and correctly executed, Birmingham has continued from that period to be the great and principal place of manufacture for this destructive weapon. See GUN

Leather appears to have been manufactured here in great quantities in the early periods of the history of Birmingham; but in 1795, there was but one tanner in the place.

Within the last century, the manufacture of steel into almost every kind of toy and ornament took its rise: a large street bears the name of Steel-house-lane, from the extensive works carried on there. Here are also very large brass works erected on the banks of the canal, on the road to the five ways, near which stand the ruins of the mansion built by the late John Baskerville, who made great improvements in the art of printing. See BASKERVILLE.

Places of Amusement and Curiosity. In New-street is a museum, or repository of natural and artificial curiosities, the property of J. Bisset, a gentleman who has published some ingenious poems and useful books. His "Magnificent Directory," is a novel, handsome, and useful work, in which are contained elegantly engraved, emblematical cards of address of a great number of the merchants, manufacturers, tradesmen, &c. throughout England.

The first *Theatre* established at Birmingham was situated in Moor-street about 1740; that in King-street was erected 1765, and enlarged 1774; in the same year it was transferred to a religious society; and another built in New-street, at an expence of 5660l. and managed with great success by Mr. Yates. In 1791, it was burnt by some incendiaries, who have never been discovered; since that period, the proprietors have rebuilt it in a very splendid manner for 14,000l. with an assembly room and a tavern annexed to it. Mr. Macready of Covent Garden theatre, is the present manager, who generally presents his audiences with the best London performers during the summer months. Concerts and musical parties are held weekly during winter; and the summer produces a variety of public gardens, the principal of which are Vauxhall and Spring-gardens.

Government. Birmingham is governed by three acting magistrates; the officers chosen annually are the high-bailiff, who inspects weights and dry measures, and the markets; the low-bailiff, who summons juries, and chuses all the other officers; two constables and one headborough; two high tasters, who examine the quality of beer and its measure; two low tasters or meat conners, who inspect the meat exposed to sale, and cause that to be destroyed which is unfit for use; two affeirers, and two leather-sellers, whose offices are now only nominal.

Deritend, a hamlet of Birmingham, sends its inhabitants to the court leet of that town, where all the above officers are chosen and sworn, in the name of the lord of the manor.

An act of parliament passed in 1752, which established a *Court of Requests*, consisting of 72 commissioners, three of whom are a quorum; they sit every Friday morning in a room of the Red Lion inn; the clerks attend to give judicial assistance, who are always professors of the common law, and chosen by the lord of the manor and the commissioners for life: ten of the commissioners are ballotted out every other year, and ten others elected from among the inhabitants. The beneficial effects of a humane society for the recovery of suspended animation were first extended to Birmingham in 1790. About the same period a committee of respectable inhabitants was established to watch over the common interests, under the title of the "Commercial Committee."

In 1791, W. Villars, esq. then high bailiff, opened a market for haw, straw, &c.

A public library was founded in 1779, which has flourished greatly, and contains nearly 10,000 volumes, supported by upwards of 500 subscribers. An elegant pile of building was erected in Withering-street for the purposes of the institution in 1797. A rival made its appearance in 1796, with every prospect of success; besides those, there are medical and law libraries, and many reading societies. Birmingham contains two churches, and four chapels; besides several meeting houses.

Churches. St. Martin's church, denominated the Old church, was raised previously to the year 1300. It is of stone, and occupies the site of, or is the first sacred building belonging to the place. In 1690, it was thought necessary to case the church and tower with brick. The walls support the arms and monuments of several titled and ancient families. Under the south window are two of white marble, one of which is supposed to have been erected for William de Birmingham, who was captured by the French at the siege of Bellegard in 1297. He wears a short mantle, &c. and bears a shield with the bend lozenge. This church was repaired and altered in 1786, at an expence of 4000l. The patronage belonged to the family of Birmingham till 1537, since which period it has been possessed by the Dudleys, the crown, the Marrows, the Smiths, and finally the Tenants. The rectory was valued in the king's books 1291, at 5l. per annum, and in 1536, at 19l. 3s. 6d. The income is now upwards of 1000l. and expected to be 2000l. after the expiration of certain leases.

St. Philip's, or the *New* church, is a handsome pile of building, but how Mr. Hutton or any other person could fancy and say that the steeple is erected after "the model of St. Paul's in London, but without its weight," is to us inconceivable, as there is not a line of it that reminds the spectator either of the dome or turrets of the metropolitan edifice. It must be allowed that the tower of St. Philip's finishes with an attic and a diminutive cupola, but there ends the resemblance. This church is advantageously situated on an eminence, and the site was given by Robert Philips, esq. It was begun by act of parliament in 1711, under a commission consisting of 20 of the neighbouring gentry appointed by the bishop of the diocese under his episcopal seal. In 1715, it was consecrated, and finished in 1719, at the real cost of only 5012l. though the estimated value was nearly 20,000l. This circumstance arose from the gift of materials, &c. The church-yard consists of four acres, and is intersected by handsome walks, shaded by trees in double and treble rows, and is surrounded by elegant buildings. Two thousand persons may be conveniently accommodated in St. Philip's church, which has contained nearly 3000. William Higgs, first rector, founded a theological library for the use of the neighbouring clergy, and bequeathed 200l. to augment it. The Rev. Spencer Madan erected a room in 1792, adjoining the parsonage, and termed it the parochial library. The rectory is worth about 300l. per annum.

St. Bartholomew's Chapel, capable of containing 800 persons, was erected in 1749, on a site given by John Jenneus, esq. an opulent land-holder of Birmingham. Mrs. Jenneus, through the good offices of Mrs. Weaman, added 1000l. and the remaining sum was received in contributions from pious inhabitants. The chapel and tower are handsome, and the former presents a line north and south. The altar-piece is the gift of Basil, earl of Denbigh, and the communion plate that of Mary Carless.

St. Mary's Chapel was erected in 1774; on a spot of ground given by Mary Weaman, whose family has the patronage. The incumbency is valued at 200l. per annum.

St. Paul's Chapel is a stone building erected in 1779, by virtue of the same act which founded St. Mary's. Charles Colmore, esq. gave the ground; a steeple is intended, and the east window was decorated in 1791, with painted glass, representing the conversion of St. Paul, by Francis Eginton, who received 400 guineas for the same.

The house of a celebrated physician of Birmingham, Dr. Ash, was purchased in 1789 by an attorney, who converted it into an elegant chapel, at the expence of his own ruin, where he caused the service of the church to be chanted by a numerous choir, accompanied by an organ. Dr. Croft, and some other clergymen, afterwards purchased it, and engaged to officiate there regularly. The congregation chiefly consists of soldiers from the neighbouring barracks.

Dissenting Meeting Houses. Old Meeting-street received its name from the old meeting erected in the reign of William III. which was destroyed in 1791 by the mob. The trustees recovered 1390l. 7s. 5d. damages, and rebuilt the present building, at an expence of 5000l.

The *New Meeting* built 1730, shared the fate of its parent in 1791, and has never been rebuilt. The celebrated Dr. Priestley presided over the spiritual concerns of this place of worship at the period of its destruction, and narrowly escaped personal injury, or perhaps death, from the furious populace. He fled, and finally retired into exile, within the state of Pennsylvania, where he died 1804, with the fame of an excellent philosopher and experimentalist. (See PRIESTLEY.) The trustees having lost their licence, could not recover damages, but the king granted his warrant upon the treasury for 2000l.

The *Union Meeting* in Livery-street, originally an amphitheatre for the exhibition of equestrian exercises, being unoccupied at the period of the riots, the congregations of the two meetings hired, and converted it into a place of worship. After the re-erection of the old meeting, they separated, resigning the Union meeting to the new

affembly, who occupy it till their place of worfhip is re-built.

Carrs-Lane Meeting, a kind of chapel to the old meeting, was erected in 1748. This fociety has 800l. bequeathed by John England in 1771, and 40l. 18s. per annum, termed Scot's truft.

A *Baptift Meeting* in Canon-ftreet, was founded in 1738, and has continued profperoufly to the prefent period.

The *Quakers* have a meeting in Bull-ftreet, frequented by a large, peaceable, and rich congregation; behind it is a fpacious burial-ground. The methodifts are now very numerous; previous to 1782, there was but one congregation, whofe place of worfhip had been a theatre; whence they removed to a fplendid meeting in Cherry-ftreet, crected at an expence of 1200l. John Weftley, their chief prieft, preached in it for the firft time July 7, in the above year; three others have fince been erected and purchafed in Colehill-ftreet, Deritend, and Newhall-ftreet. The laft was erected as a new Jerufalem temple, for the Swedenborgians, but in too magnificent a ftyle for their revenues. The methodifts bought it, and the original poffeffors built a fmaller temple.

A fmall *Roman Catholic Chapel* is fituated at Eafy-hill, in the place of one deftroyed during the deftructive riots. A Jewifh fynagogue, a baptift's meeting, and an independent meeting, lady Huntingdon's meeting, and fome other places of worfhip, are found in this town, which, like moft manufacturing places, is diftinguifhed for its number of diffenters of different fects.

Charities. Some of the ftreets of Birmingham are kept in repair by emoluments arifing from fmall eftates. William Lench, who lived in the reign of Henry VIII. bequeathed certain eftates to the town. in truft to fixteen inhabitants, for repairing the ftreets. This perfon founded the almshoufes in Steel-houfe lane for poor widows. Fentham's truft is 100l. per annum, and applied to teaching poor children reading, and for cloathing ten poor widows. The date of the donation is 1712. Mr. Crowley gave in 1733, fix houfes for the fupport of a fchool for ten girls.

The *Free School* was erected on the fite of the guild of the holy crofs, which had an endowment of lands for the maintenance of two priefts, worth twenty marks per annum, given by Thomas de Sheldon, John Colefhill, John Goldfmith, and William Attflowe. In 1393, the bailiff and inhabitants obtained a patent for augmenting the foundation, and adding a brotherhood, which flourifhed till the general diffolution, and was then valued at 31l. 2s. 10d. per annum. Edward VI. granted the lands belonging to the guild in 1552, at the fuit of the inhabitants to nineteen perfons, as bailiff and governors of the free grammar fchool of king Edward VI., to hold in common foccage at a rent of 20s. per annum. Their fucceffors erected the prefent building in 1707, which is large and handfome, has a neat tower in the centre, and a ftatue of Edward VI. in front. The chief mafter's falary is 120l. the fecond 60l. two ufhers 40l. each for writing and drawing, and a librarian 10l. There are feven exhibitions of 25l per annum each for the univerfity of Oxford, and the poffeffions are valued at 1200l. per annum.

The *Blue Coat School* was erected 1724, but enlarged and improved in 1794, at an expence of 2500l. The revenues are 1327l. and 150 boys and 40 girls receive the benefits of the inftitution.

The *Diffenter's Charity School* was held at the old meeting, but after that was deftroyed, a building was purchafed in Park-ftreet, and has been much improved. The children received are 40 boys and 20 girls.

The *Work-houfe* erected 1733, coft 1173l. a wing was added for an infirmary 1766, and another in 1779, at an expence of 1100l. The inhabitants pay a rate of 6d. in the pound, which raifes 17,000l. per annum, and relief is afforded to 7000 perfons. There are twelve overfeers.

The *General Hofpital* was erected 1766, and two wings were added 1791. It is fupported by voluntary contributions, and many large bequefts; the phyficians generally give their affiftance gratis.

The *Prifons* in Peck-lane and Deritend are difagreeable and unwholefome, and both are licenfed as public houfes.

The *Canal* between this place and Wednefbury, was made in confequence of an act obtained in 1767. It is twenty-two miles in length, uniting with the Staffordfhire canal; the fhares were 140l. each, and the expence 70,000l.; they fold in 1782 for 370l. each, and in 1792 for 1170l. Sir Thomas Gooch leafed the proprietors fix acres of land at 47l. per annum, which they converted into a wharf, and erected a handfome office on it. The boats are drawn by one horfe, and are about twenty-five tons burthen. Coals are little more than half the price they were before this canal was made. Several other canals, equally beneficial, have fince been completed, opening a communication between this town, and almoft every principal town in the kingdom.

The *Barracks* ftand on five acres of land, held by government at one penny per yard. They were erected in 1793 for 13,000l., and will accommodate 162 men.

There are three extenfive Breweries near Birmingham, Richards's in Deritend for ale, Giles and Forrefts, Worftone-lane, for ale and porter, and the Britannia, Walmer-lane, belonging to Clay and co.

The riots, already alluded to, conftitute an unpleafant feature in the hiftory of this town, and whilft they ferve to characterize the folly and infatuation of the lower claffes of fociety, will, we truft, operate as a warning example to the rifing generation. A few perfons affembled at the hotel Birmingham, July 14, 1791, to celebrate the anniverfary of the French revolution. A mob collected round the houfe, broke the windows, and immediately proceeded to Dr. Prieftley's new meeting. This, and the old meeting, were foon burnt to afhes, and the doctor's houfe and furniture, with his valuable library, apparatus, and MSS. fhared the fame devaftating fate. On July 15, the manfions of John Ryland, efq. at Eafy-hill, and Bordefley-hall, the feat of John Taylor, efq. together with the houfe, ftock in trade, books, furniture, &c. of Mr. Hutton, author of the "Hiftory of Birmingham," were deftroyed. Saturday the 16th witneffed the deftruction of Mr. Hutton's houfe at Saltley, the refidences of George Humphreys, William Ruffel, and John Taylor, efqrs. The latter, Bordefley-hall, was occupied by lady Carhampton, mother to the duchefs of Cumberland, but neither her blindnefs through age, nor connection with the king, could prevent the mandate of removing her furniture from the mob, who frantickly offered to affift: "She was therefore, like Lot, haftened away before the flames arofe, but not by Angels." The reverend Mr. Hobfon's and Mr. Harwood's houfes were next burnt; thofe of the Rev. Mr. Coates, Mr. Hawkes, and Thomas Ruffel, efqrs. were plundered. On Sunday the 17th, Kingfwood meeting perifhed in flames, the parfonage-houfe, and that of Mr. Cox, licenfed for public worfhip. The mob this day plundered Edgbafton-hall, Dr. Withering's, and attacked Mr. Male's houfe, but hearing in the evening, that a troop of horfe approached, they gradually difperfed, after deftroying property to the amount of 60,000l. To reimburfe the fufferers, an act was obtained in 1793. The war fucceeding, greatly injured Birmingham, and this cannot be more

clearly proved than by referring to the 1875 uninhabited houses in the year 1800. There are two morning papers published at Birmingham; Aris's Birmingham Gazette, and Swinney's Birmingham Chronicle, &c. Mr. Swinney also carries on a considerable type foundery, which is the only provincial one in the kingdom. " This neighbourhood," says Mr. Hutton, " may justly be deemed the seat of the arts, but not the seat of the gentry. None of the nobility are near us, except William Legge, earl of Dartmouth, at Sandwell, four miles from Birmingham. The principal houses in our environs are those of the late sir Charles Holte at Alston; sir Henry Gough Calthorpe at Edgbaston; George Birch, esq. at Handsworth; John Gough, esq. at Perry; and John Taylor, esq as Bordesley and at Mosely, all adjoining to the manor of Birmingham; exclusive of these, there are many retreats of our first inhabitants, acquired by commercial success." Hockley Abbey, near Soho, is the residence of Mr. Richard Ford, an ingenious smith, who had the honour of presenting his majesty with an iron carriage made by himself. It is a modern curious building, with the upper part representing a ruin, and is surrounded by beautiful grounds and walks, interspersed with fanciful curiosities. The most *considerable* seats in the vicinity of Birmingham, are Hagley, 12 miles distant; Enville, 18 miles distant; and the Leasowes, six miles distant. The latter will long be preserved in the memory of every reader of Shenstone, whose creation it was, and whose taste it displayed in an eminent degree. It now belongs to Charles Hamilton, esq. who has judiciously restored the neglected beauties of the place. Hagley, the seat of lord Littelton, has been particularly celebrated in the writings of Pope, Thomson, Hammond, and other poets. Enville, the seat of the earl of Stamford, is a scene of great natural beauty. For further particulars relating to Birmingham, its manufactories and neighbourhood, see Hutton's " Hist. of Birmingham," 8vo. Shaw's " Hist. of Staffordshire," fol. " A companion to the Leasowes, Hagley, and Enville," 12mo. Bisset's " Poetic Survey round Birmingham," 8vo. Phillips's " History of Inland Navigation," 4to. &c.

Bismuth

BISMUTH, *Bismutum*, Wallerius; *Wismuth*, or *Bismuth*, Germ; *Bismuth*, Fr.; *Plumbum cinereum*, *Antimonium femininum*, *tin-glass*, of the older chemists.

Bismuth is a brittle metal, of a reddish white colour, and foliated fracture, is fusible at nearly the same temperature with lead, soluble with ease in nitric acid, and precipitable from it in the form of a white oxyd by the addition of pure water.

§ 1. *Ores of Bismuth.*

Sp. 1. *Native Bismuth. Gediegen Wismuth.*

The colour of this mineral is silver-white, with a slight tinge of red, frequently exhibiting an iridescent appearance on its surface. It occurs very rarely in mass, being generally disseminated, or investing; it is also met with feather-shaped, or reticular, or in lamellæ of a rectangular or triangular shape, either solitary, or heaped upon each other. It exhibits a metallic lustre of considerable brilliancy. Its fracture is perfectly foliated, or broad striated. It is semi-ductile, and breaks with some difficulty into irregular, somewhat blunt-edged fragments. Sp. grav. according to Kirwan = 9.57.

Native Bismuth is fusible at a very moderate temperature, often by the heat of a common candle; when exposed to the action of the blowpipe on charcoal, it volatilizes in the form of a white vapour, not unfrequently accompanied with an arsenical smell. It dissolves very easily, and with effervescence, in cold nitric acid; and is precipitable in the form of a white powder, on the addition of pure water.

The only two substances, with which native bismuth is liable to be confounded, are the sulphuret of bismuth and dendritical silver; the former of these, however, is not soluble with effervescence in cold nitric acid; and the latter may be distinguished by its colour and ductility.

Bismuth is one of the most partially diffused metals hitherto known; and it is chiefly found native, accompanied with kupfernickel, white and grey cobalt, black blende, native silver, and rarely galena. Its gangue is quartz, calcareous spar, or baroselenite; and it has hitherto been found only in veins in primitive mountains.

It is found at Joachimsthal, in Bohemia; at Freyberg, Annaberg, &c. in Saxony; in Sweden, Transylvania, and Britany.

Sp. 2. *Sulphuretted Bismuth. Wismuth glanz*, Emmerling. *Bismuth sulphuré*, Hauy.

The colour of this substance is between lead-grey and tin-white; but on the surface it is usually yellowish or iridescent. It is found either lamellar and in mass, or disseminated, or in small acicular crystals. Its primitive figure, according to Hauy, is that of a quadrangular prism. Its internal lustre is metallic and very brilliant; its fracture is broad or narrow striated, or foliated like galena. Sp. gr. according to Kirwan, = 6.131. It stains the fingers in a slight degree; and when reduced to powder, is of a glistering black.

When exposed to the blowpipe, it melts easily, giving out a sulphureous odour and a blue flame, and is almost entirely volatilized before it can be brought to the metallic state. There has been no very accurate analysis made of this ore; but from the experiments of Sage and La Peyrouse it appears to contain about 60 per cent. of bismuth, 36 of sulphur, and a little iron. There is some external resemblance between the lamellar variety of this mineral and galena; but the superior fusibility of the former is an easy and infallible characteristic.

Sulphuret of bismuth is very rare; and, where it occurs, is always accompanying native bismuth. It is found at Joachimsthal, in Bohemia; Altenberg and Johann-Georgenstadt, in Saxony; and at Bastnas, near Riddarhytta, in Sweden.

Sp. 3. *Oxyd of Bismuth, Bismuth ochre*, Kirw. *Wismuth-ocker*, Emmerling. *bismuth oxydé*, Hauy.

This mineral is of a greenish yellow colour, passing into ash-grey, or straw-colour. It is sometimes found in mass, but more commonly disseminated or investing. It is opaque, and possesses a slight degree of internal lustre. Its fracture is fine-grained, uneven, or earthy. Sp. grav. considerable, but has not yet been accurately ascertained. It is either friable, or of the consistence of chalk, but occasionally gives fire with steel, on account of the particles of quartz with which it is mixed.

When exposed to the action of the blowpipe on charcoal, it is very easily reducible to the metallic state. It is soluble in nitric acid without effervescence, and precipitable for the most part by the addition of water.

Oxyd of bismuth is an extremely rare mineral. It has hitherto only been found at Schneeberg, in Saxony, accompanying native bismuth; in the Black Forest mines, in Swabia; and at Joachimsthal, in Bohemia. It is often confounded with the green earthy iron ore; but may be at once distinguished by its easy reduction before the blowpipe. Emmerling, vol. ii. p. 434, &c. Wiedenmann, p. 887. Brochant, v. 2. p. 434. Hauy, v. 4. p. 184. Kirwan, vol. ii. p. 263.

§ 2. *Assay and Analysis of Bismuth Ores.*

Sulphur and iron are the only substances that have been as yet detected in combination with this metal, as far as can be inferred from very imperfect analyses of the preceding ores. But Klaproth, in his examination of the bismuthic silver ore from Shapbach (Analyt. Ess. vol. i. p. 556.), found it to be a combination of lead, silver iron, copper, and sulphur, with bismuth; and from the experiments of this able chemist is deduced the following general method of analysing the ores of bismuth.

Having reduced the ore to a tolerably fine powder, pour upon it, in a capacious flask, five times its weight of nitric acid previously diluted with one third of water. The acid will begin to act immediately, without the assistance of heat; nitrous gas will be disengaged in great quantity; and the solution will assume a greenish yellow colour. When the acid has taken up as much as it can, or nearly so, pour it off, and digest the undissolved residue in a moderate heat, with equal parts of nitric acid and water, renewing the

menstruum from time to time, till all the soluble parts of the ore are taken up. Add together the solutions, and reduce them by gentle evaporation to about half their bulk (if any crystals are deposited, add a little pure warm water just sufficient to take them up again); then pour the whole into a large quantity of rain water, at least twenty times the bulk of the solution. The liquor will immediately assume a milky appearance, and, by standing a short time, will deposit a white heavy precipitate (*a*), which, when carefully lixiviated, is *pure oxyd of bismuth*. Add all the liquors together, and concentrate them by evaporation to one half of their bulk; then drop in a strong solution of muriated ammonia, as long as any precipitate takes place; decant the supernatant fluid as accurately as possible, and, without washing the precipitate, digest it for some time with moderately strong nitric acid; the undissolved part of the precipitate being separated, washed, and dried, is *pure muriat of silver* (*b*). The nitrous solution is now to be diluted with a large quantity of cold water, and a precipitate of oxyd of bismuth (*c*) will be thrown down. The diluted nitrous solution being mixed with the other liquor, the whole must be evaporated, till a considerable number of crystals are deposited; at this time, the addition of sulphuric acid will occasion a white deposit of *sulphat of lead* (*d*). The remainder of the solution is now to be supersaturated with caustic liquid ammonia, by which the *iron* will be deposited in the state of brown oxyd (*e*), and the copper will form with the ammonia a blue solution; this being saturated slightly to excess with sulphuric acid, will deposit the *copper* (*f*) upon a piece of clean iron. The residue of the ore that was undissolved by nitric acid, being weighed, and exposed to a low red heat, will give out its *sulphur* (*g*), the quantity of which may be estimated with considerable accuracy by the loss of weight. It is now finally to be digested with ten times its weight of boiling muriatic acid, by which some oxyd of lead will be taken up; and this, by evaporation and the addition of sulphuric acid, may be procured in the state of sulphated lead (*h*). The residue being washed and dried is the stony gangue of the ore (*i*).

Hence the ore will be decomposed into

Oxyd of bismuth (*a*) and (*c*),
Muriated silver (*b*),
Sulphated lead (*d*) and (*h*),
Oxyd of iron (*e*),
Metallic copper (*f*),
Sulphur (*g*),
Stony matrix (*i*)

§ 3. *Reduction of Bismuth ores.*

The separation of this metal from the substances with which it is found united in the mine, and the reduction of it to a marketable state, is perhaps the easiest of all the metallurgical processes, on account of the ready fusibility of bismuth, and its being found for the most part in the metallic state. The following were the methods practised in the time of Agricola (De Re Metallica, p. 349.) A round pit, two or three feet wide, was lined with well rammed clay and charcoal, and covered with billet wood, upon which were laid alternate strata of ore and wood. When the pile was thus built to a sufficient height, fire was applied to the top, and the bismuth, as the heat penetrated through the mass, became melted, and trickled down into the hole beneath, where it collected in an irregular mass; being then withdrawn, and broken into pieces, it was remelted in iron or earthen pots, separated from the impurities that floated on its surface, and finally cast into flat cakes, or loaves, for sale. Another method was to divide a large pine tree longitudinally, and cut out the central part of the wood, thus forming it into a gutter; this being placed somewhat inclined, the ore was laid in the upper end, on a bed of chips and small wood, sufficient, when set on fire, to liquify the bismuth, which, flowing down, was collected in a hole or vessel placed at the end of the trough.

The scarcity of wood has, however, put an end to these rude and extravagant methods; and the ores of bismuth are now reduced in a common reverberatory furnace, the bed of which is lined with charcoal, whence the melted metal is removed in iron ladles, and cast into masses weighing twenty or thirty pounds, in which state it is brought to market.

§ 4. *External Characters and Physical Properties.*

Bismuth is a white metal with a reddish yellow tinge; is considerably hard, but brittle, exhibiting a broad foliated fracture; has a bright, almost specular metallic lustre; and is somewhat sonorous, when struck. Though brittle, it may be compressed very considerably by judicious hammering, and therefore varies greatly in its specific gravity. According to Muschenbroeck, its sp. gr. when fresh melted, is $= 8.716$; but when laminated, is $= 9.638$. Bergman fixes its gravity at 9.67; and other authors make it as high as 9.8, or even 10. The laminæ, of which this metal is composed, have but little adhesion to each other; hence the primitive form of its crystals, which is that of a regular octahedron, may very easily be ascertained by dissection. It is fusible at 460° Fahr., and may be poured into a paper cone without burning it. If, after it has begun to solidify, the fluid part is poured off, a groupe of crystals is obtained in cubes, or rectangular volutes. When exposed in close vessels to a violent heat, it sublimes and attaches itself to the cooler part of the apparatus in the form of brilliant plates.

§ 5. *Oxyds of Bismuth.*

The combined action of air and moisture upon bismuth, at the usual temperature, is very slight; it becomes covered with a reddish grey superficial tarnish, and afterwards appears to undergo no further change. At a melting heat, it shortly becomes covered with an iridescent film, and by exposing fresh substances to the air, is wholly converted into a yellowish brown oxyd, weighing about $\frac{1}{12}$ more than the original metal. This oxyd melts into a yellow glass at a moderate red heat, and soon penetrates through the most compact earthen crucibles, though not quite so easily as glass of lead does. When bismuth is exposed to a strong heat, with free access of air, it burns with a faint blue flame, and throws up at the same time a copious white oxyd, which was formerly called *flowers of bismuth*; towards the end of the process the oxyd acquires somewhat of a yellowish tinge, probably on account of a small portion of sulphur, or other impurities. The glass, or vitreous oxyd of bismuth, is a very active flux for earths and the more difficultly fusible oxyds; on account, however, of the superior cheapness and efficacy of lead, it is seldom used for this purpose.

§ 6. *Action of Acids on Bismuth.*

1. Concentrated sulphuric acid has no action on bismuth, except when boiling hot; in this state, it is rapidly decomposed, giving out sulphureous acid gas, and reducing the metal to a white pulverulent oxyd; by a low red heat the decomposition is so complete, that a quantity of actual sulphur is volatilized. The white mass being washed with a little warm water, parts with nearly the whole of its acid, holding a small portion of bismuth in solution: this fluid, by careful evaporation, deposits minute soft crystalline needles of sulphat of bismuth, from which, by the mere affusion of water, the metal may be separated in the form of white oxyd. The sulphated oxyd, produced in the first

part of the procefs, is remarkably more difficult of reduction than any of the pure oxyds of § 5.

2. Sulphureous acid is incapable of attacking metallic bifmuth, but readily combines with its oxyd, forming a white infoluble fulphite of a fulphureous flavour, reducible into metallic globules before the blowpipe, decompofable with effervefcence by fulphuric acid, and when diftilled, giving out its acid, a mafs of pure white oxyd remaining behind.

3. Nitric acid acts upon bifmuth in a remarkably violent manner. If the metal is in powder, and the acid fomewhat concentrated, at the inftant of their mixture, even without the affiftance of heat, a rapid decompofition of the acid takes place, accompanied with the production of nitrous gas, azot, and fometimes of ammonia; and the bifmuth is converted into a white oxyd. If the acid is previoufly diluted with an equal weight of water, and the bifmuth is added gradually in fmall pieces, the decompofition goes on more quietly, the metal is diffolved in proportion as it oxydates, and the acid may be made to take up nearly half its weight of bifmuth. By cautioufly adding to this folution an equal bulk of diftilled water (each portion being well mixed with the whole mafs by ftirring, before the addition of a fucceeding portion), a black pulverulent precipitate takes place, which has not yet been analyfed, but has been taken for fulphur or charcoal. If the acid made ufe of is ftill more dilute, confifting, for example, of four parts of water, and one of nitric acid, the black matter is not diffolved. Nitrat of bifmuth, when thus purified, is clear and colourlefs, and by gentle evaporation cryftallizes in the form of flattened rhomboids, or compreffed tetrahedral prifms terminated by three fided pyramids. This falt, when expofed to a dry air, is confiderably efflorefcent; but in a humid air, becomes covered with a white, fomewhat moift coating of oxyd. When thrown on hot coals, it detonates feebly, giving out faint red fparks, and leaves behind a greenifh yellow oxyd of difficult reduction. If a cryftal of nitrated bifmuth is thrown into fome pure water, it immediately becomes covered with a white opaque oxyd; but the decompofition of this falt is more ftriking, if a folution of it is made ufe of. For this purpofe, let a jar be nearly filled with clear rain water, and drop into it nitrat of bifmuth as long as any precipitation takes place, then mix the whole by agitation, and let it ftand for an hour to fettle. The bottom of the veffel will now be covered with a fine heavy powder of a dazzling white, which, when repeatedly wafhed and dried, is pure oxyd of bifmuth, formerly called *magiftery of bifmuth*, and well known as a cofmetic under the name of *blanc de fard*. This preparation, if made with pure nitric acid, and well wafhed, is of a dead white; but if a little muriatic acid is mixed with the nitric, and the precipitate is wafhed with a *fmall* portion of *cold* water, it will be in the form of minute glittering fcales with a beautiful pearly luftre, and is then called by the French *blanc de perles*. In both ftates it is extenfively employed, particularly by the French ladies for whitening the fkin, but is fubject to turn grey, brown, and even black, by any hydrogenous and fulphureous vapours. This oxyd of bifmuth does not appear to retain any nitric acid; and its component parts are fixed by Bergman at 77 of metal, and 23 of oxygen; but, by the more accurate experiments of Klaproth, its contents are afcertained to be 81 of metal to 19 of oxygen. Nitrated bifmuth is not, however, totally decompofable by water; for the clear fluid, that is feparated by filtration from the oxyd, may ftill be made to yield a precipitate by a carbonated alkali, muriatic acid, or muriated ammonia. Klaproth found (Analyt. Eff. vol. i. p. 557.), that 100 grains of bifmuth, diffolved in nitric acid, yielded with water 88 grains of oxyd, and 35 more were obtained from the diluted folution, by the action of muriatic acid added in drops as long as any precipitate enfued. This oxyd is very eafily reduced by fufion in a covered crucible, with a little nitre and tartar.

4. Bifmuth in the metallic ftate is acted upon with difficulty by muriatic acid, even when it is concentrated and affifted by heat. During the digeftion, a fmall quantity of fetid hydrogen gas is given out; and, by flow evaporation, fmall deliquefcent needle-fhaped cryftals are depofited of muriat of bifmuth. This falt, however, may be obtained in much greater quantity, and more eafily, by fubftituting the oxyd of bifmuth for the pure metal. If the faline mafs, which remains behind after evaporation to drynefs, is diftilled in a glafs retort, nearly the whole of it comes over at a moderate heat, and concretes into a foft white mafs, called formerly *butter of bifmuth*. Butter of bifmuth, like butter of antimony, is intenfely cauftic to the tafte, deliquiates in a moift air, and when dropped into water, is decompofed, a fine white oxyd being precipitated.

5. Liquid oxy-muriatic acid acts upon metallic bifmuth with confiderably more energy than muriatic acid does: the metal is oxydated without the difengagement of hydrogen, and the refult is muriat of bifmuth. It is probable, that by fubftituting the oxyd of bifmuth for the pure metal, oxymuriat of bifmuth might be produced: this, however, is not as yet confirmed by experiment. If bifmuth, previoufly reduced to fine powder, is poured into oxymuriatic acid gas, the metal is inftantly ignited and oxydated, and falls in a fhower of fire to the bottom of the veffel.

6. Tincture of galls, or gallic acid, precipitates bifmuth of a greenifh colour from its folution, as pruffiated potafh does of a yellowifh colour.

7. There is fcarcely any thing known concerning the other bifmuthic falts. They are formed by digefting the yellow oxyd in the various acids that have not been already mentioned, and are for the moft part but little foluble in water. The proportions of their ingredients have not been afcertained with any accuracy, nor are they applied to any ufe.

§ 7. *Action of the Alkalies and Earths on Bifmuth.*

The fixed alkalies have no effect on metallic bifmuth, but unite both in the humid and dry way with its oxyd. Ammonia is faid to acquire a greenifh yellow colour by digeftion with the metal when pulverized, and certainly diffolves its oxyd in confiderable proportion. The action of the earths upon bifmuth is unknown, except that filex and oxyd of bifmuth combine by fufion into a clear greenifh yellow glafs.

§ 8. *Action of the Neutral Salts on Bifmuth.*

None of the neutral falts in folution appear to exert any affinity on bifmuth or its oxyds; but, in a dry heat, many of them are decompofed by it.

Nitre, being mixed with pulverized bifmuth, and projected into a red hot crucible, is decompofed with a flight detonation; the bifmuth becomes oxydated, and then unites in part with the alkaline bafe of the nitre.

Muriat of foda, according to Pott, is in fome degree decompofable by metallic bifmuth. This fact, however, is not confirmed by later chemifts; and it is probable, that the falt, which Pott made ufe of, was not free from muriated magnefia, and that the bifmuth was partly oxydated.

Muriated ammonia is totally decompofable by oxyd of bifmuth. On the firft impreffion of the fire, very pure ammoniacal gas is difengaged; and by a low red heat, the muriated bifmuth rifes in the form of a thick white vapour, which concretes, in the receiver and neck of the retort, into *butter of bifmuth*; if the oxyd of bifmuth is in very fmall

proportion to the muriat of ammonia, the greater part of this salt rises entire, but mixed with a little muriat of bismuth, forming the *bismuthic flowers of sal-ammoniac* of the old chemists. When these flowers are thrown into water, the bismuth is deposited in the form of a white oxyd.

Oxymuriat of potash mingled with powdered bismuth, and projected into a hot crucible, is decomposed with great violence, and the metal is completely oxydated. A mixture of three parts of this salt, and one of bismuth, produces a flash and a loud detonation, if laid on an anvil and struck smartly with a hammer.

§ 9. *Bismuth with combustible Bodies.*

If one part of sulphur, and four of bismuth, are triturated together, and afterwards exposed to a full red heat in a covered crucible, a brilliant striated metallic mass of sulphuret of bismuth is obtained, similar in its properties to the native sulphuret mentioned in § 1. It may be made to crystallize, by allowing it to cool very gradually, and pouring off the fluid part as soon as the surface is crusted over. The cavity thus formed will be found to be lined with long tetrahedral prisms crossing each other, and occasionally of a deep iridescent blue and red colour, forming groupes of exquisite beauty. The sulphuret of bismuth is much less fusible than the pure metal; it parts with nearly the whole of its sulphur by long roasting, and is decomposable by nitric acid, which dissolves the bismuth without touching the sulphur.

Sulphuretted hydrogen converts the white oxyd of bismuth into a black mass, of which neither the properties nor proportions have been ascertained.

Phosphorus has very little affinity for this metal. Pelletier tried in vain by several methods to prepare phosphuret of bismuth. In some of his experiments, the metallic globule, when red hot, gave out a faint lambent flame, but exhibited no other proof of combination with phosphorus. Fat oils, by the assistance of heat, dissolve the oxyd of bismuth, and form with it a thick tenacious plaster.

§ 10. *Alloys of Bismuth.*

Bismuth appears to increase remarkably the fusibility of all the metallic compounds into which it enters; but it is to be lamented, that we are greatly in want of accurate experiments on this interesting branch of inquiry.

1. *Bismuth and Gold.* See GOLD.
2. *Bismuth and Silver.* See SILVER.
3. *Bismuth and Iron.* See IRON.
4. *Bismuth and Copper.* See COPPER.
5. *Bismuth and lead.* Equal parts of these two metals unite easily by simple fusion, forming an alloy of a brilliant white colour, considerably harder than lead, and, though not ductile, more malleable than pure bismuth. By diminishing the proportion of bismuth, the malleability of the mass is increased, without sensibly impairing its fusibility, hardness, and lustre.
6. *Bismuth and tin.* A small quantity of bismuth increases the hardness and brilliancy of tin, without rendering it less ductile; hence the best foils for glass mirrors are made of this alloy, as also are some kinds of pewter.

Bismuth with lead and tin. Fusible metal. Plumbers' solder. The fusibility of the alloys of bismuth is in no instance so remarkable as in that discovered by Newton, and thence commonly called Newton's fusible metal. It is made by melting together eight parts of bismuth, five of lead, and three of tin. The mass is very brittle, and when broken exhibits a porcellanous appearance, with little or no lustre; it is so fusible as to become liquid when held on a piece of stiff paper over a candle, without scorching the paper; and becomes as fluid as quicksilver in boiling water. If the bismuth is reduced to one part, the proportions of lead and tin remaining the same, the alloy is plumbers' solder; and it differs from the preceding in being somewhat less fusible and considerably malleable.

7. *Bismuth and Mercury.* See MERCURY.
8. *Bismuth and Iron.* See IRON.

§ 11. *Medical Use of Bismuth.*

The magistery, or white oxyd, is the only form of bismuth which is employed medicinally. It is prescribed with success in spasmodic affections of the stomach. Gren. System. Handbuch, v. iii. p. 292. Leonhardi's Macquer. art. Wismuth. Fourcroy Syst. des Connaiss. Chimiques, vol. v. Beaumé Chem. experimentale, vol. ii.

Bits

BITS, or BITTS *for Horses*, in the *Manege*, are pieces of iron of various figure and construction which, being placed in the horse's mouth, serve, by the assistance of the reins, to restrain or guide his motions.

The term *bitts*, or *bits*, is considered by some as originating from the horse's biting or champing them between the teeth when placed in his mouth; in the French language is used a term also of similar signification, *les mords*, which would seem to corroborate the above etymology of it:—another however, equally natural, presents itself in the common word *bit*, or *bitts*, that is *pieces* of iron; this apparatus being always made of one or more pieces of this metal.

The art of bitting horses may be said to consist in furnishing the mouth with the most proper mouth-pieces, &c. for obtaining from them an obedience to the will of the rider, and exacting a due performance of all the movements and restraints which may be desired, or at least which are dependent upon the operation of the reins. Rightly understood, and well administered, this art affords the power of communicating to the horse support and confidence, with greater ease and security to the rider. The misapplication of its rules, on the contrary, or an inattention to them, where the mouth is not totally insensible, will produce painful sensations to the horse, with disgust and rebellion, and to the rider uneasiness and perhaps danger.

It is to be lamented that the presumptuous opinions of the uninformed have been too much the guide of the public in their estimation and choice of the proper bits for horses, as also in too many other things respecting these useful animals, tending often to accumulate unnecessary suffering and misery upon them. The writers on this subject are few and unsatisfactory; we shall, however, except Mr. Berenger, whose work is a noble effort to emancipate this branch of science from barbarity and ignorance; and from him we shall take occasion to make some extracts in the sequel of this article. Here it will be proper to observe, that this author, by the term *bit*, has designated the curbed bit only, but we have ventured, for the sake of pursuing a more connected view of the subject, to include in this term any piece or pieces of metal placed in the horse's mouth, for the purposes of guidance or restraint.

In our account of the different kinds of bits, and their effects, we shall begin, for the sake of order, with the description of a bit of the most easy and simple construction possible, and then proceed to the most complicated.

A short iron rod, made rather wider than the mouth of the horse, and provided with a hook or ring at each extremity for fastening the reins to, affords us an instance perhaps of the greatest possible simplicity in the construction of a bit; and such a one only slightly curved forwards, to allow more liberty for the tongue, is at present in general use for the heavier kind of draft horses, the bearing rein being usually attached to it, passing over the hames of the collar.

A similar rod to the former, broken in two pieces, and connected by a joint in the middle, is the next in point of simplicity, and is in common use for horses of light draft; as in those employed for the curricle, coach, &c. and is attached by the bearing rein to the hook of the saddle, and this kind of bit is mostly termed with us a *bridon*.

The next in point of farther complication of parts, and which scarcely can be said to differ from the former, is the *common snaffle*. This is provided with two cross pieces, which rest against the lips or sides of the mouth; for as the snaffle is intended for the saddle horse, and the reins go to the hands, so the cross pieces are useful in preventing the bits from being drawn through the mouth, which precaution is not so necessary where the bits are affixed to the bearing rein. The bridon we may observe, is also made in general smaller than the snaffle, as well as without cross pieces.

The distinction, however, between a bridon and snaffle is insignificant and of little consequence; for on all occasions cross pieces are the most convenient; and it will be easily seen that the bridon is merely an imperfect snaffle, possessing no peculiar characters which can form a real distinction.

The term, also, when confined to this object is misapplied; for the French, from whom we have borrowed it, by *le bridon* understand the snaffle and its rein, in opposition to *le bride*, by which they denote the *curbed bit* and reins.

In war, and on other occasions, the *bridon* was used as a lesser bridle, or bridle of reserve, in case of the failure of the former from any accident; and hence the origin of its name.

The number of parts of which the mouth-piece of the snaffle is composed, may be increased to any extent, as it may be made with one, two, or several joints; but as it is evident these additions will not essentially alter its properties or effects, it would be useless to pursue a distinct consideration of them.

But the condition of the snaffle admits of being so altered and changed by the variation of its figure, its substance, and its surface, as to acquire new properties and effects which will require particular attention; its gentleness or rigour will depend almost wholly on these conditions. A mouth-piece made of two entirely straight pieces will be more severe than when these are somewhat curved, as the curved bit is more apt to embrace and include the lips between it and the bars than the

the ſtraight one. A thin and ſlender bit or ſnaffle, it will be eaſily perceived, will reſt with more ſeverity and ſharpneſs upon the bars than a thick and obtuſe one; the former, therefore, or the ſharp bit, is employed more particularly for reſtraining ſuch horſes as are hard mouthed, and too eager, while the latter is uſed for ſuch as have a proper feeling of the bars, and eſpecially for breaking in young colts.

The ſurface may be varied as to roughneſs or ſmoothneſs, producing alſo different effects. To give the greateſt eaſe poſſible, a large and highly poliſhed bit is neceſſary. This is ſometimes provided with moveable rollers on the axis of the bit, which, turning with every movement of the reins, diminiſh the friction of the bits, and render them leſs irritating. Theſe rollers, however, in reality can have but little effect in the ſnaffle, though of pleaſant effect in the mouth piece of the curb; for this reaſon, that the ſnaffle being jointed in the middle, is drawn by the reins to a ſharp angle in the mouth, ſo that theſe rollers are preſented to the bars in an oblique direction, under which poſition it will be obvious they can have very little or no motion, but, on the contrary, they will tend to render the bits more ſevere by their irregularity; ſo that a well poliſhed ſnaffle is in fact preferable to one of theſe with rollers of the ordinary conſtruction.

On the other hand, to give the greateſt degree of ſeverity to the mouth piece of the ſnaffle, it is twiſted while hot into a ſpiral form, and is made to preſent by this means a ſharp, rough, and unequal ſurface to the jaw, being capable, according to the degree of ſharpneſs to which the edges are wrought, of puniſhing the bars and lips with greater or leſs ſeverity. The different degrees of puniſhment which this kind of bit is capable of inflicting, will perhaps be found ſufficient for all the purpoſes of correction, where recourſe may properly be had to actual force and puniſhment. For it ſhould be always kept in view, that gentle means will produce a good mouth; while harſhneſs and too great ſeverity will tend to deſtroy it altogether.

Thus far the ancients of the moſt remote ages of the world, almoſt as far back as any hiſtory extends, were well acquainted with the uſe of bits. Xenophon, more than 400 years before Chriſt, had deſcribed ſimilar bits as being in common uſe in his time among the Grecian ſtates. He ſpeaks of a ſmooth and a ſharp kind of bit, the latter, if more ſeverity was requiſite, to be armed with points or teeth. In its uſe, however, he enjoins the greateſt tenderneſs, and obſerves, "that when you would wiſh to ſlacken the pace of an eager horſe, which hurries on too faſt, and to pacify his fury, ſo as to make him go more temperately, or even oblige him to ſtop, you ſhould not attempt to do it at once, and with violence, but artfully, and by degrees, gently pulling him in, then yielding the bridle, and playing with his mouth, in ſuch a manner as if you intended rather to win his conſent than force his obedience." Chap. 9, 10.

Beyond the changes above deſcribed, the ſnaffle itſelf does not appear to admit of any alterations worthy of notice. It may, however, be juſt obſerved, that ſome horſemen add a chain to it, extending from cheek to cheek, which reſting looſely on the tongue produces irritation and ſlavering, and, as they imagine, freſhens the mouth. Such a bit is known by the name of the *Rockingham ſnaffle*.

The reins, however, it muſt be remarked, admit of ſome alterations in their diſpoſition, which will influence the effects of the bit on the mouth; as whether they are carried higher or lower. At this preſent time there is a practice more eſpecially in horſes of light draft, as in thoſe for carriages, curricles, and chairs, &c. to diſtort and alter the bearing reins from their natural direction, and to diſpoſe them more perpendicularly and in a line with the head; ſo that inſtead of paſſing ſtraight from the mouth to the horſe's back, they are directed up the ſides of the face, as high nearly as the parotid gland, or baſe of the ear, where they are paſſed through a ring hanging from the head ſtall, and from thence to the hook of the ſaddle. The appearance is ornamental and elegant, and the reins ſo diſpoſed are conſidered as more forcibly elevating the head than if they proceeded to the back in the uſual direction.

As the diſpoſition of the reins, ſo the *figure* of the bits themſelves, and the ornamental appendages attached to them, admit of almoſt endleſs variety. The manufacturers of theſe articles, availing themſelves of this licence, render their buſineſs more lucrative by as frequent changes as poſſible. Theſe are ſucceſſively introduced as faſhionable novelties, till again for novelty they return to the ſimpleſt practice; and this takes place without any alteration in the principal circumſtances of their conſtruction, properties, or uſe.

The next kind of bits in uſe for horſes is the curbed bit; which, as it is an inſtrument of much greater complication of parts than the ſnaffle, ſo it appears to have been of comparatively recent date.

In ſome of the ſculptured equeſtrian figures of the ancients ſomething like the branches of the curb may be found; but in no inſtance does there appear any thing reſembling the chain, which is abſolutely neceſſary to its effect. Their writings alſo appear to be ſilent on this ſubject. It was probably the invention of Italy or France, which for ſome centuries paſt have taken the lead of the other nations of Europe in teaching the arts of the manege. It was firſt introduced into the Engliſh army by a proclamation made in the third year of king Charles I. ſince which time it has got into univerſal uſe for the army, the field, and the road, ſo that no horſeman deems himſelf perfectly equipped without it. Moſt of thoſe writers who have treated of it in the laſt, and in the century preceding that, and who wrote probably ſoon after the commencement of its uſe, have been very profuſe in their various propoſals for the ſtructure of it, eſpecially in rendering it more complicated, ſevere, and cruel; though it is probable their clumſy figures and repreſentations were never imitated in actual practice. They appear to have been much ſatiſfied with their new invention, imagining it a ſure means of reducing horſes to immediate obedience, in ſpite of every obſtacle; and true it is, it can puniſh with extreme ſeverity: but is ſuch a meaſure moſt likely to create vice, or to overcome it? Indeed, according to the opinion of one of the ableſt writers that has ever conſidered this ſubject, and whoſe opinion we ſhall take an opportunity of quoting more fully hereafter, little or nothing has been really gained by its adoption; on the contrary, the ſnaffle poſſeſſes more ſimplicity, power, and perfection.

Stripped of all unneceſſary trappings, this inſtrument conſiſts of the following eſſential parts: a mouth-piece with two ſide branches, or inflexible rods of iron, firmly fixed to the former, and a chain paſſing from ſide to ſide, behind the chin, including the jaw; two eyes or rings at the upper extremity of theſe branches, ſerve to faſten it to the head-ſtall, and to ſtay it in the mouth; two other rings at the lower extremity of the above branches receive the reins, paſſing to the hand, or ſometimes in draft horſes to the hook of the ſaddle, as a bearing rein. Theſe are all the parts really neceſſary to conſtitute the curb.

The bits thus formed being placed in the mouth, and the chain paſſed round the lower jaw, the branches, it will be

readily ſeen, become powerful levers when drawn backwards, acting upon the mouth-piece as a centre, and ſqueezing, by means of the chain, whatever interpoſes between it and the mouth-piece, with a force equal to the length of lever afforded by the lower branch.

This force, it will be perceived, is influenced and regulated not only by the length of the lever below the mouth-piece, but alſo by the greater or leſſer diſtance at which the chain is placed from it. The chain is uſually fixed to the eye of the cheek-piece, where the head-ſtall is faſtened; if, therefore, this part is very long, it is evident it muſt moderate or counteract the power and effect of the lower end of the branch, and render it leſs ſevere by bringing the centre of motion nearer to the middle of the lever.

It appears manifeſt, from the conſtruction of this inſtrument, that its whole force is exerted upon the jaw itſelf, and that it has power to pinch the bars with cruel violence, even to the fracture of the bone, and this with very powerful branches has ſometimes happened. It can alſo cruſh and bruiſe, and totally deſtroy the tender covering of the inſide of the mouth, and the ſkin beneath the jaw.

From conſidering its mode of operating, it might reaſonably be doubted whether it does in reality ſtop the horſe by its power and oppoſed force, as is generally conceived at preſent, or rather by the ſeverity of the pain it inflicts; as ſhould the horſe arm himſelf againſt this, it is totally inſufficient to arreſt his courſe; of which inſtances occur in runaway horſes every day. And we ſhall venture to ſuggeſt, though contrary to the general opinion, that the ſnaffle, even in this reſpect, if the mouth has not been previouſly hardened aud ſpoiled by the uſe of the curb, is the moſt powerful inſtrument of the two.

The *mouth-piece* of the curb is uſually provided with an upſet or arch in the middle of it, as it would, if perfectly ſtraight, reſt on the tongue, and occaſion an unpleaſant reſtraint. This paſſage for the tongue is often made ſo narrow and ſmall by the bit makers, that one ſhould apprehend they ſcarcely had a right idea of its uſe. From the circumſtance of its allowing a paſſage for the tongue, it has been called by ſome, the *liberty;* and, for the ſame reaſon, by others, the *porte:* hence we have the porte-mouth bit, vulgarly called among the bit makers and grooms the *Portſmouth* bit: and by a ſuppoſed counter expreſſion to this term, we probably get the *Weymouth*-bit.

In draft horſes, eſpecially for the coach, it is a frequent cuſtom to have affixed to the upper part of the upſet ſmall chains or poliſhed drops of iron, which hanging looſe in the mouth, and falling on the tongue, occaſion the horſe to champ the bits, and create a copious flow of ſaliva, ſo as to ſlaver the lips with its white froth; and when this happens, it is conſidered by ſome a good ſign of health and gaiety, and that the horſe is well bitted; for, if the bits are diſagreeable to him, he never plays with them, or exhibits any froth, ſay they. Theſe ſmall appendages are termed by the French *les chainettes*, and by the Engliſh *players*.

It is farther to be obſerved, reſpecting the mouth-piece of the curb, that the ſtraight part which reſts upon the bars of the jaw, is termed by the French *le canon*, and by the old Engliſh writers the *jeive;* and though a highly convenient and uſeful word, it is to be regretted it is at preſent out of uſe; the French term, which is not ſo expreſſive, having ſuperſeded it. This part ſhould be well poliſhed, and may be made of any proper figure, as that of a cylinder, cone, oval, globular, pear-ſhaped, &c.

It is obvious that the effect of the curb, as far as it reſpects the bars, will be correſpondent to the thickneſs or thinneſs, ſmoothneſs or roughneſs, of this part; the larger and broader it is, the more ſurface it covers; and thus the preſſure, by being diſtributed over more points, becomes leſs felt. This enlargement, however, of the canon or jeive ſhould not be carried to an exceſs, by making it too heavy, or filling the horſe's mouth with more iron than it can conveniently receive, and thus create pain, inſtead of greater eaſe.

To render theſe irons leſs irritating to the mouth, and to avoid their friction upon the bars, the jeives are provided with looſe, moveable rollers of well poliſhed iron, which readily turning on the axis of the bits, very conſiderably diminiſh their ſeverity. Theſe moveable pieces are alſo particularly uſeful in preventing the horſe from catching and holding the bit in his teeth; as the curb, under theſe circumſtances, can ſtill move and act with the ſame freedom as before.

The jeives are ſometimes compoſed of three or four flattiſh knobs, united by a joint to each other, and with a joint to the upſet, which is intended to render it very ſevere; it is obvious, however, that ſuch an alteration muſt bring it nearer to the condition of the ſnaffle; the knobs, however, if they can be drawn tranſverſely acroſs the bars, might produce conſiderable irritation, but not ſo much as they would do if not jointed. This bit is not unfrequently uſed, and is called with us the *Heſſian*-bit.

To the curb is often fixed a ring oppoſite the mouth-piece, which, as it is directly in a line with the axis of the bit, has no other effect when the reins are affixed to it, than a ſnaffle would have provided with a ſimilar mouth-piece. This is termed putting "the reins to the cheek," and for horſes of light draft, whoſe mouths are not ruined, it is by much the beſt, as the mouth is leſs annoyed, and the horſe obeys with more alacrity the guidance of the hand from this point, than from the extremity of the branches, which are particularly ill calculated for this purpoſe: this kind of conſtruction is generally diſtinguiſhed by the name of the *Pelham* bit.

In the older Engliſh writers, as well as thoſe on the continent, on the ſubject of bits, we find an appendage deſcribed, which is not at all, at preſent, in uſe; and as it enters the mouth with the mouth-piece, it may, with propriety, be deſcribed along with it. It conſiſted of a chain extending from branch to branch of the banquet, or cheek piece, being placed rather above the mouth-piece, and parallel to it, and was ſtretched acroſs perfectly ſtraight and tight. This part was called the *water-chain*, and by the French *Trenche-file:* its uſe is not very evident. Mr. Berenger takes notice of it, and obſerves "that it might be uſeful to horſes that are apt to drink or ſwallow the bits, as the expreſſion is, or bury it ſo deep in their mouths, as to hinder it from having a due and juſt effect;" from its being laid aſide ſo generally, we preſume it has at leaſt been thought uſeleſs.

It is a common belief with the grooms, that a great power reſides in the upſet of the mouth-piece, and that the bits are more powerful as this is longer or ſhorter; nothing, however, can be more fallacious than this reaſoning. In the works of Laurence Reeſe, alſo a French writer, we find, in conſonance with this idea, a curb, with an upſet of unuſua length, being deſtined to correct the vices "d'un Rouſſin qui à la bouche d'une diable;" it will be obvious, however, on a moment's reflection, that this part, from being made very lofty, and coming forcibly againſt the palate, would compel the horſe to open his mouth, when it would ceaſe farther to act in any way; with more reaſon, the ſame writer propoſes, on the other hand, "pour donner

grand plaisir," to have a bit constructed with a low upset, and sufficiently wide, with large, conical, smooth jeives for the bars.

Of the chain. The chain is the part most essentially necessary to give effect to all the other parts of the curb, and may be placed, as we have already noticed, at any given distance above the mouth-piece; its operation being more powerful, as this distance is exceeded by the length of the branches. This position, though true as a general principle of reasoning, appears to be subject to the operation of other causes in actual practice, which it will be necessary to consider; for, in direct contradiction to this is the assertion of Mr. Berenger, who appears to be almost the only writer who has truly investigated the merits of this particular object. He observes, in regard to this, that the nearer the chain, and the longer the branches, the softer and more indulgent its operation. This, on a first view, would appear to be in direct variance with the rules above laid down, and irreconcileable to the well known laws of the operation of the lever, and even at variance with his own preceding assertions; when, however, we remember the experience and practical knowledge of him who asserts it, it deserves a more particular consideration; let us first admit the truth of the position, as it seems founded on the sure test of actual experience, and then we should venture the following as the most natural explanation of it.

In proportion as the branches are longer, the more extensive is the circuit their extremities perform in their operation; and therefore, the hand that guides them must pass through a greater space to produce the same effect: and now, if the chain be placed very near to, or upon the outside of the mouth-piece, and be applied not very tight about the chin, yet, in reality, though there would be an apparent increase of power by the length of the branches, they would have little or no effect, as they would arrive at the utmost extent to which they can be drawn, before the chain would begin to pinch. On this account, the most lively effects would be produced by the chain having more sweep and extent of action, and by the branches being not quite so long, as great length also adds something to their flexibility, though not to a degree to be worth taking into the account. Still, however, the branches must ever obey the common laws of the lever, acting with force proportioned to their length; while shorter branches act with greater quickness, and are more lively in their impression.

The chain is fastened on one side to the eye of the banquet, where the head-stall is fastened; on the other, to a hook hanging from the same part. This chain, as it is at present used, is composed of iron links or rings, so beat or indented, as to form, when put together, one uniform nearly flat surface; and these links, by twisting or untwisting, may be made to present a surface with any degree of roughness to the chin.

When great tenderness is required, this chain may be covered with leather or cloth; or where a still greater delicacy is desirable, the curb may be made wholly of leather, without any chain.

The larger and thicker the rings are, provided they are smooth and well polished, the easier the effect of the chain. In old English, this chain was called the *kirble*; and hence, by contraction, *kirb*; and finally, by an easy transition of the *ki* into *cu*, we apprehend that the modern appellation of this instrument is obtained.

Of the branches. The proportion which the cheek part bears to the lower extremity of the branches, or rather the position of the eye, to which the chain is fixed, determines the degree of power of the bit upon the principle before advanced; that is, if the chain is fixed to the upper extremity of it, as it usually is to the transverse opening or eye of the head-stall.

For the elementary view we are taking of the construction of the bits, it has been only considered as a straight, plain lever of indeterminate length; it is, however, in practice, often varied, as in the army, it is used of enormous length, and frequently curved like the letter S, by which it is conceived to be rendered more powerful, as well as ornamental; at other times the branch of the bit, with a view of increasing its force, is carried forward with a sharp elbow, giving nearly the figure of the letter Z; while by others, with more reason, to prevent the horse from catching the bit in his mouth, it is made with an arch, or semicircle, in the middle of the branch, like the letter C, turned backwards for the same purpose; still, however, in fact, whether bent into that or any other shape, it is the length of the lever, and its strength, which alone give the power; it is true, however, that a long curved branch, though more powerful, will render the effect somewhat softer, as coming from a greater distance, especially if the branch is at all flexible and yielding, than it would by the quick and rigid effect of a shorter lever, made perfectly straight and inflexible: these branches may also be turned or bent, not only backward or forward, but also outwards and inwards. At their extremities, those turned outwards, are said to be strongest of any in their operation.

As to the cheek-piece, or banquet, as it is called by the French, for an appropriate name is wanting to this part in the English language; the eye of the banquet, say the horsemen, commands and gives efficiency to the rest of the bit; or, in other words, decides the distance of the chain from the mouth-piece, or centre of motion; as, however, in speaking of the other parts, we have had occasion to introduce a sufficient account of this, it will not be necessary farther to give it a separate consideration; nor will it be useful to describe the numerous mongrel herd of bits engendered of the snaffle and curb, which are reducible to the properties of one or the other, or partaking of both.

The most useful bit of the curbed kind, appears to be the *Weymouth*-bit, which is at present in common use for draft horses of light work, as for carriages, coaches, &c. It consists of a strong, plain mouth-piece, of uniform thickness throughout, without any upset or jeives, but is simply curved forwards, to give liberty to the tongue: this kind of construction is the simplest perhaps that the curb admits of.

In concluding, it remains for us to notice the proper application and adjustment of these bits to the horse's mouth, and to treat of their real effects.

By the management of the head-stall, the snaffle bits should be so adjusted as to fall in the middle space between the tushes and grinders, resting upon the bars: the mouth-piece of the curb should also occupy the same situation; when, however, it is used along with the snaffle, the bits of the snaffle should be placed highest in the mouth.

If the bits are placed too high in the mouth, the horse carries his head aloft; if too low, he stoops the head, and tries to catch them in his teeth.

The thicker and more fleshy, and the wider or broader the bars of the horse, the rougher may be the mouth-piece for the leaner and more delicate; consequently, the bits should be less severe. Care should also be taken that the mouth-piece be well suited to the size and width of the mouth, and be not too narrow, as this would give pain, by squeezing the bars together: if, on the contrary, it is very wide, it rests with more force on the bars, without the interposition

of the lips, as is most usually the case. Where the tongue is large and prominent, the upset should also be in proportion, otherwise the bits could not rest upon the bars, but would press upon the tongue.

In regard to bitting the horse, and the consideration of its effects, we cannot desire to see any thing more consonant to truth and reason, than what has been given us by Mr. Berenger, and with some useful extracts from his valuable performance, we shall conclude this article.

Of bitting horses with the curb. " In the beginning of an undertaking, whose aim is to subdue and reclaim nature, and that at a time when she is wild, ignorant, and even astonished at the attempts which are made upon her, it is evident that she must not be treated but with lenity, instructed with patience, and by small degees, and that nothing should be offered that may hurt, surprize, or occasion any disgust.

The horseman, therefore, should not act the part of a tyrant, but of a lover; not endeavour to force her to submission, but strive to gain her consent and good will by assiduity, perseverance, and the gentlest attentions; for what prospect of success would rougher manners afford? To what purpose would it be to compel a colt to go forward, or turn from fear of the whip or spur, and to trot and gallop so freely as to supple his limbs, and form his paces; if the novelty of the bit, and the unaccustomed restraint to which it subjects him, should vex and confound him, so as to make him not know what to do, or how to behave in these extremes? It cannot be expected, that he will be guided, and go with ease to himself, or pleasure to the rider, if the instrument, by which he is to be conducted, offends or gives him pain: all habits and acquirements should be attained gradually, and almost imperceptibly: rigour and precipitation would ruin all; and, instead of forming the horse to the execution of what is required, may plunge him into vice and rebellion, so as to occasion much trouble and loss of time before he can be reduced.

He should not therefore, at first, be considered as if he was designed to be formed to all the delicacy and exactness of the bit; and the horseman should be content, if he will endure it in his mouth, so as to grow, by little and little, accustomed to it, till the restraint becomes by habit so familiar and easy, that he not only is not offended, but begins even to delight in it; for this purpose, great care should be taken that the bit be easy and gentle in all its parts; that the mouth piece be larger than it need be for an horse already bitted; that it in no wise incommodes the bars, squeezes the lips, or galls the tongue.

The mouth-piece, called a cannon, with a joint in the middle, will be the most suitable; the ends of it should be as large and full as the size of the mouth will permit, for the thicker and more blunted they are, the easier they will be for the horse, and the *appui* less strict and severe.

The links of the curb should be big, smooth, and well polished; the curb somewhat long. The branches should be exactly even with a line of the banquet, to make the appui moderate and equal; they should likewise be long; nor does it signify of what shape they are, for with most horses they ought to be so weak, as scarcely to have any effect: so requisite it is to guard against every thing that may annoy or disturb the horse in these first trials. In order to reconcile him to this new constraint, the reins should be held in both hands; and the horse, for some time, should only walk under the rider. Above all, upon this, and all other occasions, a firm, a light, and diligent hand, is necessary.

Such are the outlines and general principles upon which the art of bitting horses is established; which art, as far as it reaches, is sure and constant; but which, in spite of all the merits and praise of which it has so long been in possession, will, upon a serious and strict trial, never, I doubt, be found adequate to the views of a sound and intelligent horseman, nor capable of bringing a horse to that degree of suppleness and exactness of carriage, which the truth and perfection of the art require, these attainments seeming to have been reserved for a more simple but powerful machine, called the *snaffle*."

" To perform his business justly and gracefully, the animal must first be made supple in his fore parts, and his head and neck so managed, that one may be raised, and the other arched or bent, more or less to the hand to which he is to turn. The bridle, called the bit, is so impotent in its endeavours to raise the head, that it even produces the opposite effect; nor from the confinement in which it keeps the horse, and the small compass it affords for the action of the rein, does it allow the rider sufficient room to bend him, without pulling down his head, and putting him upon his shoulders, both of which are incompatible with the true and sound principles of the art. The frequent use of cavesons and bridons, fully evinces the want of power in the bit to supple the horse, or raise the fore part.

The figures and representations of horses working upon different lessons, may be appealed to for the confirmation of this assertion: the books of past times abound with them, especially that boasted work of that king of horsemen, the duke of Newcastle, whose horses are all drawn with their heads between their knees; and yet are exhibited to the equestrian world as standards of truth, and models of perfection. The successors of this duke, and of other great masters, as imitators, are generally a blind and servile herd, ran headlong into the errors, and adopted the faults of their predecessors; and always made use of bits, without reflecting upon their effects, or perceiving that they could operate to make the horse carry low, or to put him upon his shoulders, while they thought that he was all the time upon his haunches."

" If ever there was a panacea, or universal medicine, the snaffle is one for the mouths of horses: it suits all, and accommodates itself to all; and either finds them good, or very speedily makes them so; and the mouth once made, will be always faithful to the hand, let it act with what agent it will. This bridle can at once subject the horse to great restraint, or indulge it in ease and freedom: it can place the head exactly as the horseman likes to have it, and work and bend the neck and shoulders to what degree he pleases. He can raise the head, by holding up his hand; by lowering it, it can be brought down; and if he chuses to fix and confine it to a certain degree he must use for this, as well as for the purpose of *bending*, *double reins*; that is, two on each side, the ends of which must be fastened in a staple near the pommel of the saddle, or to the girths, higher or lower, as the mouth, proportions of the horse, and his manner of going require; and if properly measured and adjusted, they will form and command the horse so effectually, as, in a great degree, to palliate many imperfections of the mouth, and many faults in the mould and figure."

" The reins thus fastened, or even one only, for the sake of working one jaw and one side, will operate more or less, as the branches of a bit: and the snaffle will almost be a bit, a bridon, a caveson, and martingal, in one. When the horseman would bend the horse, he must pull the rein on that side to which he is going, and lengthen that of the opposite, that they may not cour[illegible] each other. No-

thing will awaken a dull mouth, and bring it to life and feeling, so soon as this bridle. If the mouth be hard and callous, the iron should be so twisted as to have a sort of edge, which will search the lips, and when they will permit, the bars also; and if gently moved, or drawn from side to side, keep the mouth fresh and cool. If the twisted, or rough snaffle, be thought too harsh, and the hand not skilful enough to moderate its effects, a smooth snaffle may be used; or if a bit of linen be wrapt round the twisted snaffle, it will make it easy and smooth; and the mouth, once made fine and delicate, will be true to its feelings, will obey the snaffle, and follow the hand with as much exactness and precision as the bit knows to demand, but with more freedom and boldness than it ever can allow."

Such are the properties and merits of the snaffle, which long observation, and not a little experience, have taught the writer of this article to think preferable (generally speaking) to those of the bit; and which he has been therefore induced to point out and recommend with due deference to others, but with a greater deference to truth and justice.

"—Detrahere ausus,
Hærentem capiti multa cum laude coronam."

Berenger's Hist. and Art of Horsemanship, vol ii. p. 221, &c.

Bit is also used for a little tool, fitted to a stock or handle, for the purpose of boring. In this sense, we say, the bit of a piercer, an augre, or the like; meaning that iron part of those tools wherewith the holes are bored.

The bit used by the block-makers, resembles the shank of a gimblet, from six to twelve inches long, and from half an inch to an inch in diameter, and has at its end either a screw, a sharp point, or edge, for the purpose of cutting or boring holes. The *centre-bit* is a bit, having in the middle of its end, a small steel point, with a sharp edge on one side to cut horizontally, and a sharp tooth on the opposite side to cut vertically. Holes bored with this instrument, are not liable to split. The *countersunk-bit* is a bit having two cutting edges at the end, reversed to each other, which form an angle from the point. *Gouge-bit* is a bit smaller than a centre-bit, with a hollow edge at its end, like a gouge. *Nose-bit* is a bit similar to a gouge-bit, having a cutting edge on one side of the end.

Bit *of a Key*, is that part fitted at right angles to the shank of the key, wherein the wards are made. See Lock, &c.

Bit is also used in *Commerce*, for a piece of coin current in Jamaica, and valued at 7½d.

Bits, or *Bitts*, in a ship denote a frame composed of two upright pieces of timber, called the pins, and a cross-piece fastened horizontally on the top of them; used for belaying cables and ropes to. *Bowline and brace-bitts* are situated near the masts; the *fore jeer*, and *top-sail-sheet bitts* are situated in the fore-castle, and round the fore-mast; the *main jeer*, and *top sail sheet bitts* tenon into the fore-mast beam of the quarter-deck; the *riding bitts* are the largest bitts in the ship, and are those to which the cable is bitted, when the vessel rides at anchor. The *cable is bitted*, or confined to the bitts by one turn under the cross-piece, and another turn round the bitt-head. In this position, it may be either kept fixed, or it may be veered away.

Bit-*Stoppers*, are those stoppers that are used to check the cable. See Stopper.

Bitumen

BITUMEN, *Bitumé*, Fr. The bitumens, properly so called, form a species of compound mineral inflammables, of which the following are the characters. 1. By exposure to the air, and the application of heat, they burn with a flame more or less vivid, and leave scarcely any residue. 2. By destructive distillation, they yield a liquid acid, but no ammonia, a variable but small proportion of charcoal being left behind in the retort. 3. They are either liquid, or capable of being rendered so by a moderate degree of heat.

Bitumens may be divided into two families, the non-elastic and elastic. To the former belong naphtha, petroleum, mineral tar, mineral pitch, and asphaltum; to the latter belong mineral caoutchou, and suberiform mineral caoutchou.

§ 1. *Non-Elastic Bitumens.*

NAPHTHA, *Bergnaphtha, Napthe, Bitume liquide blanchâtre*, is a substance of a light brown, or wine yellow colour, perfectly fluid and transparent. It is the lightest of all liquids, its specific gravity being =0.708 to 0.732: it has a strong penetrating bituminous smell; it takes fire with great readiness, and burns with a bluish yellow flame and copious black smoke, leaving no residue. It may be rectified by distillation with water, in the same manner as the essential oils, and then becomes colourless, and weaker in its odour. It does not combine in any considerable degree with either water or alcohol, but unites easily with ether, with turpentine, with caoutchou, and the essential oils. When rubbed with the caustic fixed alkalies, it form a kind of Starkey's soap. The concentrated sulphuric and nitric acids are decomposed with vehemence upon it, converting it into a solid resinous substance soluble in alcohol. Even the purest naphtha, when exposed to the air, becomes first of a yellow, and then of a brownish colour, acquires a somewhat viscid consistence, and thus passes into petroleum. Naphtha is procured for the most part from very copious springs of this substance at Baku on the shore of the Caspian sea, where it is burnt in lamps instead of oil, and is used medicinally both externally and internally in rheumatic and other complaints. It is also met with in Calabria and some parts of Italy.

PETROLEUM, or *Rock-oil. Erdohl, Stein-ohl. Petrole.* The colour of petroleum is a blackish or reddish brown; it is fluid, though somewhat viscid; it is almost opaque, is unctuous to the touch, and exhales a strong bituminous odour; its taste is pungent and acid. Sp. gr. 0.747, 0.854. Petroleum may be rectified by distillation with water, in which process, the carbon, which thickens and colours it, is left behind in the retort, and a colourless fluid comes over, possessed of all the properties of naphtha. When petroleum is distilled *per se*, there first arises some naphtha, then a watery empyreumatic acid, and lastly a thick dark-coloured oil, a spungy coal remaining in the retort. In its combinations with, and chemical actions on other substances, it perfectly resembles the preceding species. It is found wherever naphtha is, and in many other places among stratified mountains, in the vicinity of coal. In England, Coalbrook dale, and Pitchford in Shropshire, are the principal places where petroleum is found; at the latter place extensive strata of sandstone are saturated with petroleum, and the naphtha, procured by distillation of the stone, is sold under the name of Betton's British oil, and is esteemed an active remedy in strains and rheumatism.

MINERAL TAR, BARBADOES TAR, *Bergthier, Goudron mineral.* This substance differs from the preceding only in degree; it is more viscid, more opaque, of a darker colour, and, when distilled, leaves a larger carbonaceous residue. It is found native together with petroleum, and may also be procured by the distillation of coal.

MINERAL PITCH, *Maltha.* The external characters of maltha are extremely similar to those of common pitch; when heated, it emits a strong unpleasant odour. In cold weather it may be broken, and exhibits a vitreous lustre; but when warm it is soft and tenacious.

ASPHALTUM, *Schlachiges Erdpech, Asphalte.* The colour of this substance is black or brownish black; it is light and brittle; when broken, it displays a conchoidal fracture and vitreous lustre; it has little or no odour, unless it is rubbed or heated. It is considerably inflammable, melts easily, and burns away without leaving any residue. It is principally found on the shores of the Dead Sea, in Syria, and in the isle of Trinidad in the West Indies

The principal use of asphaltum is an ingredient in certain varnishes, especially that used by the copper-plate engravers.

§ 2. *Elastic Bitumens.*

MINERAL CAOUTCHOU, *Elastiches Erdpech, Poix minerale elastique.* The colour of this substance varies from yellowish brown to olivé brown and blackish or reddish brown. The light coloured is often in a semifluid state, and adheres to the fingers; the olive brown is solid and elastic; the blackish and reddish brown are hard and little elastic. It occurs stalactitical, or investing, or in masses. Its sp. grav. in the soft varieties is about =0.9, and in the hardest and least elastic is=1.2. It passes into asphaltum.

It is partly soluble in sulphuric ether; but the residue of the solution, after evaporation of the ether, is not elastic; thus forming an essential difference between the vegetable and mineral caoutchou.

This singular mineral has been hitherto only found in the cavities of a lead mine, near Castleton, in Derbyshire, called the Odin mine, accompanied by asphaltum.

SUBERIFORM MINERAL CAOUTCHOU. This substance, when recently cut, exactly resembles fine close cork in its colour and texture; but by exposure for a few days to the air, it becomes of a pale reddish brown colour. It is also sometimes found friable, and passing by decomposition into an ochraceous powder. It has only been found in a rivulet near the Odin mine, whence the preceding is obtained, and appears to differ from it, merely by being penetrated with water. It occurs in nodules of various sizes, some weighing upwards of 13 pounds, the nucleus of which is very commonly the brown perfectly elastic mineral caoutchou. Fourcroy Syst. vol. viii. Brochant. Mineralog. vol. ii. p. 58. Dict. d' Hist. Nat. art. *Bitumes.* Gren. Syst. Handbuch. vol. iii. p. i. Hatchet on Bitumens in Linnæan Trans.

Black

Black, *blue*, in the *Manufactures and Arts*, is the coal of some kind of wood, or other vegetable matter, burnt in a close heat, where the air can have no access: the best sort is said to be made of vine-stalks and tendrils. The goodness of blue-black consists in the cleanness and blue cast of its black colour, and the perfect degree of its levigation.

That this preparation, which is sold in the colour-shops, is no other than a vegetable coal, appeared from the following experiment of Dr. Lewis. (Comm. Phil. Techn. p. 358.) Laid on a red hot iron, it burned and glowed like powdered charcoal, and turned into white ashes; which ashes, thrown into oil of vitriol diluted with water, very readily dissolved into a bitterish liquor, the characteristic by which the vegetable earth is distinguished. From what particular vegetable matter this blue-black is procured, experiments, he says, cannot discover: but it appears from those which he recites, that it may be obtained from many, and that the choice of the vegetable subject affects rather the softness or hardness than the colour of the coal. Blue-black, perfectly good, may be prepared in the manner directed for *ivory* Black, from the vine stalks, or tendrils, or any other twigs of wood, of an acid taste and tough texture; but the soaking in the oil, prescribed for the ivory, must be omitted.

The painters have *blue-blacks*, *brown-blacks*, &c. which may be made by mixing pigments of the respective colours, with simple black ones, in greater or less quantity, according to the shade required. The dyers also have different blacks, and often darken other colours by slightly passing them though the black dying liquor; but the term brown-black is in this business unknown, brown and black being here looked upon as opposite to one another. In effect, the colour called brown-black is no other than that which all dyed black clothes change to in wearing; and therefore it is no wonder that it should be excluded from the catalogue of the dyers' colours. The true or simple blacks, mixed with white, form different shades of grey, lighter or darker, according as the white or black ingredient prevails in the mixt. The black pigments, spread thin upon a white ground, have a like effect. Hence the painter, with one true black pigment, can produce on white paper, or on other white bodies, all the shades of grey and black, from the slightest discolouration of the paper up to a full black; and the dyer produces the same effect on white wool, silk, or cloth, by continuing the subjects for a shorter or longer time in the black bath, or making the bath itself weaker or stronger.

M. le Blon, in his "Harmony of Colours," forms bl k by mixing together the three primitive colours, blue, red, and yellow; and Mr. Castel, in his "Optique des couleurs," published in 1740, says, that this compound black has an advantage in painting above the simple ones, of answering better for the darkening of other colours. Thus if blue, by the addition of black, is to be darkened into a *blue-black*, the simple blacks, if used in sufficient quantity to produce the requisite deepness, conceal the blue, while the compound blacks leave it distinguishable. Le Blon has not mentioned the proportions of the three primitive colours necessary for producing black. Castel directs 15 parts of blue, five of red, and three of yellow; and he observes, that the colours should be the deepest and darkest of their respective kinds, and that a combination should be made to several pigments for each colour; for the greater the contrast of heterogeneous and discordant drugs, the more true and beautiful will be the black, and the more capable of uniting with all other colours, without suppressing them, and even without making them tawney. Dr. Lewis, in his experiments, has not so far succeeded as to obtain a perfect black by mixing different blue, red, and yellow powders; but he procured very dark colours, such as brown-blacks and grey-blacks.

Black, *bone*, is made of the bones of bullocks, cows, &c. well burnt and ground. To be good, it must be soft and friable, of a glossy cast. It is in considerable use, though inferior in goodness to ivory-black.

The invention of bone, or ivory-black, is attributed to Apelles. Plin. Hist. Nat. lib. xxxv. cap. 5.

Black *chalk*. See Chalk, and Killow.

Black *charcoal*. See Charcoal, and Crayons.

Black, *curriers*, signifies a teint or dye laid on tanned leather. Tanned leather is so much impregnated with the astringent parts of oak bark, or with that matter which strikes a black colour with green vitriol, that rubbing it over three or four times with a solution of the vitriol, or with a solution of iron made in vegetable acids, is sufficient for staining it black. Of this we may be convinced by dropping a little of the solution on the unblacked side of common shoe-leather. This operation is performed by the currier, who, after the colouring, gives a gloss to the leather with a solution of gum-arabic and size made in vinegar. Where the previous astringent impregnation is insufficient to give a due colour, and for those sorts of leather which have not been tanned, some galls or other astringents are added to the solution of iron; and in many cases, particularly for the finer sorts of leather, and for renewing the blackness, ivory or lamp-black is used. A mixture of either of these with linseed oil, makes the common oil-blacking. See Currying.

Black, *dyers*, is one of the five simple and mother colours used in dyeing: and given differently, according to the different quality and value of the stuffs to be dyed. See Dyeing.

Green vitriol strikes a black colour with vegetable astringents, and hence it is the basis of the black dye for cloth, leather, hats, &c. And as solutions of iron with galls, &c. produce the same colour, a method is derived from hence of distinguishing the minutest portions of iron in mineral waters, &c. Neumann.

The substances chiefly employed for producing black colour with vitriol are galls. When a decoction or infusion of the galls is dropped into a solution of the vitriol largely diluted with water, the first drops produce bluish or purplish red clouds, which mingling with the liquor tinge it uniformly of their own bluish or reddish colour. This difference of the colour, says Dr. Lewis (Com. Ph. Tech. p. 346.), seems to depend on the quality of the water. With distilled water, or the common spring waters, the mixture is always blue. A minute quantity of alkaline salt previously dissolved in the water, or a small degree of putridity in it, will render the colour of the mixture purple or reddish. Rain-water received from the clouds, in clean glass vessels, gives a blue, but if it be collected from the tops of houses, gives purple with the vitriol and galls. Both the blue and purple liquors, when more of the astringent infusion is added, deepen to a black, more or less intense, according to the degree of dilution; and if the mixture be a deep opake black, it again becomes bluish or purplish when further diluted. If it be suffered to stand in this dilute state for two or three days, the colouring matter settles to the bottom in form of a fine black mud, which, by slightly shaking

ſhaking the veſſel, is diffuſed again through the liquor, and tinges it of its former colour. When the mixture is of a full blackneſs, this ſeparation does not happen, or in a far leſs degree; for though a part of the black matter precipitates in ſtanding, yet ſo much remains diſſolved, that the liquor continues black. This ſuſpenſion of the colouring ſubſtance in the black liquid may be attributed in part to the gummy matter of the aſtringent infuſion increaſing the conſiſtence of the watery fluid, for the ſeparation is retarded in the diluted mixture by a ſmall addition of gum arabic. If the mixture, either in its black or diluted ſtate, be poured into a filter, the liquor paſſes through coloured, only a part of the black matter remaining on the paper. The filtered liquor, on ſtanding for ſome time, becomes turbid, and full of fine black flakes: but being freed from theſe by a ſecond filtration, it again contracts the ſame appearance, and thus repeatedly, till all the colouring parts are ſeparated, and the liquor has become colourleſs. The colouring matter, thus ſeparated from the liquor, being drained on a filter and dried, appeared of a deep black, which did not ſeem to have ſuffered any change on being expoſed to the air for upwards of four months. When it was made red hot, it glowed and burnt, though without flaming, and became a ruſty brown powder, which was readily attracted by a magnetic bar; though in its black ſtate, the magnet had no action upon it. The vitriolic acid, diluted with water, and digeſted on the black powder, diſſolved the greateſt part of it, leaving only a very little quantity of whitiſh matter. Solution of pure fixt alkaline ſalt diſſolved very little of it; the liquor received a reddiſh brown colour, and the powder became blackiſh brown. This reſiduum was attracted by the magnet after being made red-hot, though not before; the alkaline tincture, paſſed through a filter, and mixed with ſolution of gum vitriol, ſtruck a deep browniſh-black colour, nearly the ſame with that which reſults from mixing with the vitriolic ſolution an alkaline tincture of galls. For an account of the reſult of theſe experiments, ſee Lewis, *ubi ſupra*. See alſo Iron.

For broad-cloths, fine ratines, and druggets, &c. the dyers uſe woad and indigo; the goodneſs of the colour conſiſts in there not being above ſix pounds of indigo to a ball of woad, when the latter begins to caſt its blue flower; and, in its not being heated for uſe above twice. Thus blued, the ſtuff is boiled with alum, or tartar, then maddered; and, laſtly, the black given with galls, copperas, and ſumac. To bind it, and prevent its ſmearing in uſe, the ſtuffs are to be well ſcoured in the fulling mill, when white, and well waſhed afterwards.

For ſtuffs of leſs value, it is ſufficient they be well blued with woad, and blacked with galls and copperas: but no ſtuff can be regularly dyed from white into black, without paſſing through the intermediate blue.

Yet there is a colour called *coal black*, or *Jeſuit's black*, prepared of the ſame ingredients as the former, and ſufficient of itſelf without the blue dye. Here the drugs are diſſolved in water that had boiled four hours, and ſtood to cool till the hand would bear it; then the ſtuff is dipped in it, and again taken out ſix or eight times. Some even prefer this black to the other. This method of dying black is ſaid to have been invented by the Jeſuits, and to have been practiſed in their houſes, where they retained numbers of dyers.

By 23 El. c. 9. nothing of the nature of cloth ſhall be maddered for a black, except it be firſt grounded with woad only, or with woad and ancle [blue ind.], unleſs the madder be put in with ſumac or galls; on pain of forfeiting the value of the thing dyed: provided it ſhall be lawful to dye any manner of gall-black, and ſumac-black [*plain black*], wherein no madder ſhall be uſed.

Logwood ſtrikes a black with chalybeate ſolutions and is employed with theſe liquors for ſtaining wood black, as picture frames, &c. With the addition of galls, it is uſed for dying cloth and hats black. (Neumann's Works, p. 385.) This black colour is not permanent, though beautiful, any more than the natural violet dye of the *logwood*.

Black may be alſo obtained by a ſolution of ſilver in aqua fortis, when the previous matter ſtained with this liquor is expoſed for ſome time to the ſun and air; and alſo from ſolutions of lead in acids, when the ſubjects to which they are applied are expoſed to ſulphureous vapours, or waſhed over with alkaline ſolutions of ſulphur. Calces of lead, melted with ſulphur, form a bluiſh or blackiſh maſs, uſeful in taking caſts from medals. (See Casts.) Beſides, when a ſolution of ſilver in aqua fortis is added to a ſolution of ſulphur made in alkaline ley, the ſilver and ſulphur unite and precipitate together in the form of a black powder. See Dying, and Staining.

Black, *earth*, is a kind of coal found in the ground, which, well pounded, is uſed by painters in freſco. See *Pit*-Coal, and Fresco.

There is alſo a kind of black made of ſilver and lead, uſed to fill up the ſtrokes and cavities of things engraved.

Black, *German*, or *Frankfort*, is made of the lees of wine burnt, then waſhed in water, and ground in mills for that purpoſe, together with ivory or peach ſtones burnt. Some ſuppoſe, that it is the coal of vine-twigs; but this, ſays Dr. Lewis (Com. Phil. Techn. p. 377.), does not appear to differ, in any great degree, from that of the ſmall branches of other kinds of trees; but the kernels of fruits yield a coal conſiderably more ſoft and mellow, eaſily crumbling between the fingers into a fine meal. That the Frankfort black is no other than a vegetable coal, appeared, from its burning on a red-hot iron, like charcoal powder, into white aſhes, and from the aſhes, like common vegetable aſhes, being plentifully diſſoluble by the vitriolic acid into a bitteriſh liquor, while the aſhes of animal ſubſtances are very ſparingly affected by that acid, and form with it a compound of a different kind of taſte.

This black makes the principal ingredient in the rolling-preſs printers' ink, which ſee. It is ordinarily brought from Frankfort, Mentz, or Straſbourg, either in lumps or powder. That made in France is more valued than that of Germany.

Black *glaſs*. See Glass.

Black, *harts*, that which remains in the retort after extracting the ſpirit, ſalt, and oil of hartſhorn. This reſidue being ground up with water, makes a black not much inferior to that of ivory.

Black, *Indian*. See *Indian* Ink.

Black, *ivory*, is made of ivory burnt or charred, ordinarily between two crucibles well luted; which, being thus rendered perfectly black, and in ſcales, is ground in water, and made into troches, or little cakes, uſed by the painters; as alſo by the jewellers to blacken the bottom or ground of the collets, wherein they ſet diamonds to give them their teint or foil. Some recommend ſoaking the chips or ſhavings of ivory in hot linſeed oil, before it is charred.

There are particular machines and contrivances for burning the ivory for theſe purpoſes, by which the colour is rendered more beautiful than that of the coal which remains in the diſtillation. Neumann.

The goodneſs of ivory black, which is the fineſt of all the charcoal blacks, may be perceived by its fulneſs, without a blue caſt; and by the fineneſs of the powder.

In the manufacture of this black much impofition is practifed, fo that what is generally fold under this name is no other than the coal of common bones. Being applied to coarfe purpofes, and fold at a low price, it is very grofsly levigated by the hand or horfe-mills which are employed in grinding the bones, and fo much adulterated with charcoal duft, which gives it a blue caft, that it is wholly exploded from delicate ufes, and lamp-black, though inferior with regard to the purity and clearnefs of the black colour, fubftituted for it.

The following recipe is given in the Handmaid to the Arts (vol. i. p. 140.) for preparing it in perfection. Take plates, chips, or fhavings of ivory, and foak them in hot linfeed oil; or, if filings are more eafily procured, they may be ufed moiftened with the hot oil. Put them into a veffel, which will bear the fire, covering them with a fort of lid made of clay and fand; which fhould be dried, and the cracks repaired before the veffel be put into the fire. Let this veffel be placed in a tobacco-pipe maker's or potter's furnace, or any other fuch fire; and let it remain there during one of their heats. When it is taken out, the ivory will be properly burnt; and muft be afterwards thoroughly well levigated on the ftone with water, or to have it perfectly good, be alfo wafhed over. The ivory may be conveniently burnt in a calcining or fubliming furnace.

An opake deep black for water colours is made by grinding ivory-black with gum-water, or with the liquor which fettles from the whites of eggs after they have been fuffered to ftand a little. Some ufe gum water and the whites of eggs together, and they fay, that a fmall addition of the latter makes the mixture flow more freely from the pencil, and improves its gloffinefs. It may be obferved, however, that though ivory-black makes the deepeft colour in water, as well as in oil-painting, yet it is not on this account always to be preferred to other black pigments. A deep jet-black colour is feldom wanted in painting; and in the lighter fhades, whether obtained by diluting the black with white bodies, or by applying it thin on a white ground, the particular beauty of the ivory-black is in a great meafure loft.

Black, *lamp*, or *lam* Black, originally perhaps the foot collected from lamps, is generally prepared by melting and purifying refin or pitch in iron veffels; then fetting fire to it under a chimney, or other place made for the purpofe, lined a-top with fheep-fkins, or thick linen cloth, to receive the vapour or fmoke, which is the black: in which manner they prepare vaft quantities of it at Paris. In England confiderable quantities are prepared, particularly at the turpentine-houfes, from the dregs and refufe parts of the refinous matters which are there manufactured; but the greateft part is brought from Germany, Sweden, and Norway. Its preparation is defcribed in the Swedifh Tranfactions for 1754, as a procefs dependent on the manufacture of common refin.—The impure refinous juice, collected from incifions made in pines and fir-trees, is boiled down, with a little water, and ftrained, whilft hot, through a bag: the dregs and pieces of bark, left in the ftrainer, are burnt in a low oven, from which the fmoke is conveyed, through a long paffage, into a fquare chamber, having an opening in the top, in which is faftened a large fack, made of fleafy or thin-woven woolly ftuff; the foot, or lamp-black, concretes partly in the chamber, from which it is fwept out once in two or three days, and partly in the fack, which is now and then gently ftruck upon, both for fhaking down the foot, and for clearing the interftices between the threads, fo as to procure a fufficient draught of air through it. The more curious artifts prepare lamp-black for the nicer purpofes, by hanging a large copper pan over the flame of a lamp with a long wick, fupplied with more oil than can be perfectly confumed, fo as to receive its fmoke. Soot collected in like manner from fir and other woods, by burning fmall pieces of them flowly under a copper pan, is of a deeper black colour than fuch as is obtained from the fame kinds of wood in a common chimney, and little inferior to that of oils. The foot of mineral bitumens, in this clofe way of burning, appears to be of the fame qualities with thofe of woods, oils, and refins. In fome parts of Germany, it is faid, great quantities of good lamp-black are prepared from a fort of pit-coal.

The goodnefs of lamp-black lies in the fulnefs of the colour, and in its being free from duft or other impurities. The lightnefs of the fubftance furnifhes the means of difcovering any adulteration, if to a great degree; as the bodies with which lamp-black is fubject to be fophifticated, are all heavier in a confiderable proportion.

This fubftance is ufed on various occafions, particularly in the printers' ink; for which it is mixed with oils of turpentine and linfeed, all boiled together.

It muft be obferved, that this black takes fire very readily, and when on fire is very difficultly extinguifhed: the beft method of putting it out is with wet linen, hay, or ftraw; for water alone will not do it.

A glafs tube clofely filled with lamp-black has been found to conduct a confiderable charge of electricity inftantaneoufly, and with fcarce any explofion. But a coating of this fubftance, mixed with tar or oil, is a perfect non-conductor, and has proved a prefervative from lightning, by repelling the electric matter from thofe parts of the mafts of fhips which have been covered with it.

Ruffian lamp-black is prepared from the foot of fir, and is collected at Ochta near St. Peterfburg, Mofcow, Archangel, and other places, in little wooden huts, from refinous fir wood, and the unctuous bark of birch, by means of an apparatus uncommonly fimple, confifting of pots without bottoms, fet one upon another, and is fold very cheap. It is three or four times more heavy, thick, and unctuous, than that kind of painters' black which the Germans call "kienrahm," and which is called in Ruffia "Holland's black." For an account of the fpontaneous accenfion of Ruffian fir-black, impregnated with hemp-oil, fee *Spontaneous* Inflammation.

A *mineral lamp-black* may be procured from pit-coal, or any kind of mineral or foffil coal, by preferving the blackeft particles of the fmoke arifing from it in ignition. Mr. Wm. Row of Newcaftle-upon-Tyne obtained a patent in 1798 for his method of manufacturing this kind of lamp-black. See the fpecification in the Repertory of the Arts, &c. vol. x. p. 81.

Black *paint*. See Paint.

Black *fand*. See Sand.

Black *fealing wax*. See Wax.

Black, *foot*, or *chimney*, is a poor colour; but ready for painting black draperies in oil. The foot blacks are in general much fofter and of a more yielding texture than thofe of the charcoal kind, and require much lefs grinding, for uniting them with oily, watery, or fpirituous liquors, into a fmooth mafs; of fome of them a part is diffolved by water, or fpirits of wine, while none of the charcoal blacks have been found to contain any thing diffoluble. This foluble matter of foots, however, is not black like the indiffoluble parts; and in this particular, as well as in the colour of the entire mafs, different forts of foot differ from one another. Thus the foot of pit-coal collected in common chimneys, of itfelf rather greyifh black than of a full black,

being infused separately in rectified spirit of wine, and in water, tinged the former of a transparent reddish colour, and the latter of a paler reddish; while the deeper black soot of wood gave, both to spirit and to water, an opake, dark brown. See Soot.

Black, *Spanish*, so called, because first invented by the Spaniards, and most of it bought from them, is no other than burnt cork used in various works, particularly among painters.

Blast

Blast, the term used at iron founderies to denote the column of air introduced into the furnace for the purpose of combustion. Its velocity is occasioned by the impelling power of the blowing machine forcing the whole contents of the air-pump through one or two small apertures called nose-pipes; and, according to the absolute power of the engine, air of various densities will be produced, so that density and velocity are always intimately connected, and mutually implied.

The well-known combustibility of iron, and the indispensible necessity of exciting combustion by the introduction of large quantities of condensed air into the furnace, in contact with ore in various states of maturity as to separation, into contact with iron existing in all the modifications of quality as to carbonation, and into contact with an immense body of ignited fuel, render this subject the most important in the major scale of our manufactures. Unfortunately for art, as well as for science, few practical deductions can be brought forward to establish any one theory of blast; one common principle only is acknowledged, that all reduction in the furnace is in consequence of the combustion excited by the column of air introduced.

To take a proper view of this interesting subject, it will be necessary to submit it to the following divisions.

1st. Combustion, as excited in this particular branch of manufacture.

2d. The nature of the fuel submitted to combustion.

3d. The density of the air.

4th. The quantity.

5th. The properties which follow as a consequence of density and quality.

1st. Combustion in the blast furnace consists chiefly in the rapid reduction of a given quantity of solid fuel, and its accompanying portion of ore, in the shortest possible time. That furnace, and that blast, which can, in a given time, reduce the greatest quantity of fuel, all things else being alike, will always manufacture the greatest quantity of iron. In common, before the introduction of the blast, the furnace is previously filled with alternate strata of coke, iron-stone, and limestone, heated by simple atmospheric pressure to a bright red or white heat, and the iron stone to a melting heat. This temperature is soon increased throughout the furnace, after the blast is applied. The blowing orifices or tuyeres of the furnace exhibit the fuel increasing in whiteness, and the iron-stone rapidly dissolving before the blast, of a blackish colour. At this period, the lava which flows from the furnace, in consequence of the reduction of the ore and lime-stone, is considerably charged with iron, and is of a black, blackish brown, or greenish brown colour. These appearances will continue for twelve, twenty-four, or thirty-six hours, according to the mode of treatment in bringing forward the furnace after blowing. The tuyere (if a bright tuyere furnace) will appear like a blaze of uncommonly pure light, at times very offensive to the eye; it soon, however, becomes accustomed to it, and can with facility discern the individual masses of coke, as they are forced away, with the rapidity of lightning, before the irresistible force of the air. The concrete ore and lime-stone are no longer visible; but a fine metallic spray is constantly descending, and, forced from the fuel, precipitates itself to the bottom of the furnace. The scoria formed by the fusion and union of the lime-stone, with the immetallic parts of the ore, is carried before the blast in a similar manner and form, but easily distinguishable from the fluid metal by its buoyancy, want of velocity when impelled, and by its dull colour. In this state, the furnace is deemed in excellent smelting order. The iron is generally revived with little loss; and the colour and purity of the cinder or lava sufficiently indicate the perfection of the separation. When at any time the brightness of the tuyere fails, and becomes dull white or reddish white, then a change is indicated; the iron-stone and lime-stone will again appear in the solid unseparated state, and the change of colour in the cinder infallibly betokens an irregularity in the movements of the furnace. These appearances are so general, as scarcely to admit of an individual exception, and are sufficient to warrant the following explanation.

At the introduction of the blast, the interior of the furnace at the tuyere was simply a mixture of ignited masses of cokes and iron-stone, the latter partly semifused, but the greatest part merely heated to a bright red heat. In the descent through the furnace, in contact with ignited coke, the particles of metal in the ore may, by parting with the oxygen, have received a disposition to become revived. The increased temperature creates an additional tendency, by establishing a greater force of affinity betwixt the fuel and the iron. But the metal approaching to its proper state, meeting the current of blast, is immediately subject to a partial combustion. The portion thus oxydated conveys to the lava in proportion to its quantity and oxygenation, the colour already mentioned.

As soon as the continuation of the blast conveys a higher temperature to the superior regions of the furnace, the appearance of the solid matter at the tuyere ceases. The fusion and separation of the metal from the ore are effected in situations more remote from the blast, or chief source of decomposition in a temperature more suited to the nature and existence of the metal. The iron, once formed into a fluid, and its fluidity preserved, its descent to the blast is attended with little or no injury to its carbonation.

To understand this distinctly, it will be necessary to state two curious facts relative to cast iron in a fluid state; and but for the existence of these properties, the manufacture of the metal in open furnaces or vessels would be totally impracticable. 1st. Cast iron, while kept fluid, never decomposes atmospheric air, and never itself becomes oxydated. 2d. The degree of carbonation passed upon the metal at the

moment it enters into complete fusion, continues without diminution or augmentation throughout the whole operation of the furnace; or, in other words, cast iron neither receives nor loses carbon whilst it preserves its fluidity. The first fact explains the reason why the iron is preserved from combustion, when it descends opposite to the current of blast. The second is a proof that the carbonaceous matter is conveyed to the iron in the furnace by a species of cementation previous to fusion; and that after this point, cast iron will not take up any addition of carbon.

To preserve and establish the relation of cementation and fusion in the furnace ensures uniform products. Combustion in this presents us with a gradation of temperature, diminishing from the tuyere upwards through thirty or forty feet of ignited matter. The inferior temperature towards the top of the furnace heats the materials to redness; an affinity is here commenced betwixt the carbonaceous matter and the oxygen of the ore; the latter is gradually removed, and a second affinity is instituted betwixt the de-oxygenated particles of metal and the carbon: this, as the ore descends to higher temperatures, is rapidly increased, and by and by the saturation of the coally principle is complete. As the saturation of carbon always increases the fusibility of iron, the metal of the furnace enters into fusion at a comparatively low temperature, and speedily precipitates, through the high temperatures in the neighbourhood of the blast, to the general reservoir below.

It is not therefore necessary to suppose, that the great volume of air thrown into the furnace, and the great temperature of course excited, are necessary to the manufacture of the iron, so far as it regards quality; this, it is more than probable, may be injured by it, and even the economy of the manufacture itself. Quantity, however, is in general secured; but this is more the effect of mechanical reduction, than of any necessary operation of the blast upon the ore and materials above.

The quicker the body of cokes can be reduced, which occupy that part of the furnace between the point of separation and the tuyere, the greater will be the reduction of the whole, and the greater the quantity of manufactured metal. To this point the whole force of the blast is directed; here the chief part of the decomposition of the atmospheric air takes place; and here the destruction of the intervening cokes is effected, and that always in proportion to the quantity of air poured upon their highly ignited surfaces.

If we assume, with a blast of a certain density, any two points in the furnace, the one as the point of decomposition, and the other of separation and fluidity of the metal, suppose the former at the tuyere, and the other at the lower end of the boshes at A, (See *description of* BLAST *furnace*,) then it must be allowed probable, that a change taking place in the density, or even in the quantity of the blast, that change will affect not only the points themselves, but also their relative distances. The point of separation may be brought nearer (and perhaps injuriously so) to the level of the blast, the elevation of which is supposed to remain the same. The contrary may with equal truth be inferred; that if the point of separation is carried to a more elevated situation by a change or increase of temperature, the ore may enter into fusion before it has remained sufficiently long in contact with the ignited fuel, and thereby both the quality and quantity may be injured.

2d. Since pit-coal coke became the staple fuel at the blast furnace, the density and quantity of air deemed necessary to ensure combustion and quantity, have been yearly increasing. The various qualities as to hardness or softness, purity and effect, have given rise to a multitude of opinions, which are the most appropriate quantity and density of air for respective qualities of cokes. The blast of the furnace, in consequence, has at different places varied from 1¼ to 4 lb. of expansive force upon the square inch of the air vessel. Most of the English works are blown with air not exceeding 2 lb. upon the square inch, as being the most proper medium of density, and beyond which the materials would be overblown. English coal, in general, is soft in its fossile state, but rich in carbon, and free from mixture. In Scotland, where the coal is found in dense strata, and forms heavy coke, the blast is used from 2 lb. to 4 lb. per inch. Those who have adopted dense blasts declare, that quantity of iron is incompatible with a column of air inferior to the measure of their standard. Either the prejudice is very general, or there really must exist a direct analogy between the nature of the blast and the density of the coal.

The operations of the charcoal pig manufactory were conducted with blasts of a trifling density, seldom exceeding 1½ lb. upon the inch, and often under this. Dense blast, it was believed, over-ran the furnace, most probably by exciting too great a temperature, and frequently had a tendency to discharge the materials from the furnace top. There never yet have been any direct experiments made to ascertain upon what this variety of pit-coal depends; whether exclusively from its density, or from containing the carbonaceous matter in more purity or greater disengagement. Perhaps both are necessary to be taken into account, before any satisfactory explanation can be given of the facts now stated and generally admitted.

3d. The density of a column of air depends upon the power of the blowing machine, and the proportion of the area of the steam cylinder to that of the blowing cylinder. Tables of the powers of steam engines, and the diameters of cylinders requisite to condense air from 1¼ lb. to 4 lb. upon the circular inch, will be found under the article BLOWING MACHINE. It will appear evident from these tables, that steam cylinders of the same diameter, and working at the same power, when employed to raise air of various densities, do not discharge the same quantity of atmospheric air in any given time. The larger the area of the blowing cylinder, the number of strokes being the same, the greater will be the quantity of air discharged into the furnace. The reverse is the case with blasts progressively more dense; so that any part of an engine's power may be employed, not in raising the true principle of combustion—air, but in condensing a comparatively small body of air, so as to give it additional velocity.

To fix the point, or maximum, of the most profitable density, has hitherto been unattainable. The circumstances, deemed intimately connected with coal, render it necessary to accommodate the blast to the combustibility of the fuel: were this not the case, it would be difficult to overturn the following reasoning, and to exhibit an instance where it might not be found generally applicable. Combustion in the furnace will be excited in proportion to the quantity of air introduced. A blowing machine, that with the same power of steam cylinder threw into the furnace double the quantity of air, though of an inferior density, would reduce a greater quantity of combustible matter than one oppositely constructed; or, in other words, 5000 feet of air per minute entering a furnace would produce greater effects than 3000 feet, although the latter were compressed into nearly half the bulk of the former.

The most plausible theory of blast is to fix upon the lowest density at which the air can be forced into the furnace, and then proportion the diameter of the air-pump to the power of the steam end. Suppose that this could be effected at half the density usually employed, then that part of the

engine's power used formerly to compress the air to 3 or 4 lb. would now be employed in a blowing cylinder of larger diameter, raising per minute, or indeed per stroke, from 100 to 200 cubic feet of air. Opposed to this there stand two formidable objections, resulting from the necessity of using blow-pipes or nozles of increased diameters, from which to discharge the additional quantity of air, making up in area what is wanting in velocity to discharge the air in a given time. The first is a re-action of the air, so powerful as to issue back from the tuyere with a velocity little short of that at which it enters. This, with nose-pipes of 2, $2\frac{1}{2}$, and from that to 3 inches, is scarcely felt when the blast is soft, and may be entirely obviated by a judicious arrangement of the tuyere iron and nose-pipe; but with pipes from 3 to 4 and $4\frac{1}{2}$ inches diameter, the recoil increases as the squares of the diameters of the blowpipes, and even in dense blasts the recoil increases with the diameter of the discharging pipe. It is therefore probable, that to blow with a nosepipe 4 or 5 inches diameter, so as to have no recoil, a velocity or density of air would be requisite beyond any thing yet in use.

Those who advocate for the use of a soft blast, either upon the plea of their materials, or as being the most advantageous method of using any given mechanical power, frequently feel the full effects of the recoil of a considerable portion of the whole blast. But to obviate this, and to gain the advantage of the whole air, the blowpipe is enclosed in a moveable frame or building, which is made air-tight at every cast, and completely prevents the return of the smallest portion of it. The combustion at these furnaces is carried on with equal effect, and the resulting products in iron equal in point of quantity and quality to those where blasts of double density are used.

Again, at other furnaces, where a soft blast had been originally preferred, the plan of forcing back the recoiled air, in order to make up in quantity what was now deemed to be deficient in density or velocity, has been in vain attempted. The tuyere irons have become immediately heated, and burnt back with violence. The materials would not admit of the tuyeres being raised sufficiently high to prevent the cinder from flowing back into the bag, which connects the large and small pipes, and destroying it. Even in more than one instance, the entire tuyere side of a furnace has been lost in endeavouring to establish this plan of blowing, where either the materials would not answer, or from some misconception in the mode of operating. Where a furnace works uniformly with a dark or honey-combed tuyere, this mode of blowing may be attended with the greatest success. In all new erections, however, the blast ought to possess of itself sufficient velocity not only to enter the furnace, but to ascend through the materials, without admitting of any important recoil.

The second objection, arising as a consequence of the want of velocity, and of being obliged to use pipes of a larger diameter to carry in the full complement of air, arises from a belief that a large pipe never makes the metal of a good quality. This deduction is perhaps not altogether correct; but it seems highly probable, that in the use of a comparatively loose blast, only a small portion of the air passes through the furnace without decomposition. The point of separation may by this means be changed, or perhaps be raised too high for the preservation of the metal, immediately previous to separation. As the increased temperature prevails upwards, the affinity between the particles of metal in the iron-stone, and the carbon of the fuel, may be earlier established, and no ultimate evil consequence, in point of reasoning, ought to ensue. It appears from numerous observations, that the quantity of iron-stone, which a given weight of cokes smelts, and to the metal of which is conveyed the carbonaceous principle, is considerably dependent upon the diameter of the blowpipe. Supposing the ore of equal richness, the smaller the pipe, the greater burden will the coke carry, and the cheaper will the iron be made per ton, so far as materials are concerned. On the contrary, with large pipes, whatever the density of the air may be, the quantity of coals necessary to manufacture an equal quality of pig iron will be increased, and the cost of the iron is also enhanced. As an equivalent for this, however, the quantity is considerably increased with nearly the same amount of labour; so that it remains a question with the manufacturer, whether the additional cost of coal is compensated by the extra produce of metal he is enabled to bring to market.

4th. The quantity of air discharged into the furnace, under the appellation of blast, depends upon the number of strokes or cylinders which the engine makes per minute, and on the area and diameter of the air pump. This is independent of every consideration of density and increase of power in the steam cylinder, so long as the blowing or air cylinder remains the same, and the engine performs the same discharges; the measure of atmospheric air, which enters the furnace, will remain the same. The rapid improvements, which of late years have been made in the blowing machine, have increased the quantity from 1000 to 4000 feet per minute per furnace; and the quantity or produce in iron has been also considerably increased. We by no means, however, find that the increased manufacture of iron has been in the exact ratio of the quantity of blast thrown into the furnace. Many instances of late years have been noticed during the transition from the old to the improved modes of blowing, wherein the proportion has had little or no similarity.

Fifteen hundred feet of atmospheric air in one minute was found in most situations equal to the manufacture of twenty tons of melting iron; in the same situations, 3000 feet in the same time has never exceeded thirty tons per week; and in one particular trial for two weeks, the discharge of 6000 feet, being the whole produce in air of the engine, the produce in iron never exceeded $36\frac{1}{2}$ tons. In the last case, the quality of the iron was irregular, and the quantity of cokes for each ton of metal thus produced was considerably increased, although the iron was of inferior carbonation.

Without recurrence to the diameter of the air cylinder, and the particular movements of the engine, the same facts have been frequently deduced from the diameters of the nose-pipes. We have frequently seen air discharged under a pressure of $2\frac{1}{2}$ lb. upon each square inch, but with a pipe of $2\frac{1}{2}$ inches diameter, reduce materials, and manufacture good melting iron to the extent of 20, 22, and 25 tons per week; and in the same furnace, and with the same materials, the air discharged by 2 pipes, each $2\frac{1}{2}$ inches, under a pressure of 3 lb. upon each square inch, the produce never exceeded 30 tons of metal of an equal quality, but more frequently 25 to 28 tons. One observation still more direct, and made with a blast of a density equal to $2\frac{1}{2}$ lb. per inch, and discharged by one pipe of $2\frac{5}{8}$ inches diameter, frequently manufactured 22 tons fine melting iron weekly; another pipe was added to the opposite tuyere of the same diameter, and the quantity of metal weekly was never increased beyond 32 tons, and upon an average of six months only 27 tons. These are curious facts relative to the nature and effects of blast, and exhibit the investigation of its principles as a matter of singular importance in the economy of the manufacture.

One remark was made relative to the burden of ore in the last stated fact, that with the small pipe a given weight of cokes smelted and carbonated the metal in 3 cwt. of iron

ſtone; but after the two pipes were added, the weight of iron-ſtone, to produce an equal quality of iron, was reduced to 2½, and afterwards to 2¼; producing in the firſt inſtance per charge 1¼ cwt. of iron upon an average, but latterly not above 1 cwt. and 10 lb. of iron of equal qualities. Another obſervation, in the ſame caſe, with every attention paid as to velocity, quantity, and temperature of air, may be adduced as of equal importance, though ſomewhat different in its mode of application.

Under a preſſure of 2 lbs. a 3¼ pipe was found upon the average of 18 weeks to manufacture 20 : 12 : 0 : 0 tons; a 3½ inch pipe, 20 : 5. Upon an average of 11 weeks, and a 4¼ pipe, 22 : 5. Their reſpective areas, and iron produced, will ſtand in oppoſition thus:

3¼ pipe,	area 10.6625	quantity of metal	20.12
3½	- - 12.25	- - -	20.5
4¼	- - 18.0625	- - -	22.17

It is but fair to ſtate that the effects of combuſtion, ſo far as it related to the reduction of a quantity of fuel, was not in the ſame unequal proportion as the quantity of metal to the meaſure of the air. The quantity of reduction was with the

3¼ pipe	equal to 25
3½	- - 31
4¼	- - 38

But the capacity of the fuel to carbonate the original quantity of iron, diminiſhed in nearly the ſame ratio as the combuſtion increaſed; ſo that the ſame meaſure by weight which carbonated 140 lbs. of iron with the 3¼ pipe, was unable to carbonate more than from 96 to 100 lb. of the ſame quality with the 4¼ pipe. This obſervation was made previous to the one laſt mentioned, and reaſoning upon the ſubject led to the practice detailed in that experiment. It will appear therefore concluſive, that the ſame body of blaſt may, with greater advantage and economy, be introduced through two pipes than through one, and this for two reaſons. The reduction is equal, and the quantity of fuel reduced, ſmelts and carbonates a larger portion of metal per charge; but it will appear from both caſes equally concluſive, that the capacity of the fuel to convey carbonation is in the ratio of the ſmallneſs of the pipe, or the reduction of the quantity of air.

This is in unison with what was ſtated under the particular "Combuſtion;" that a large volume of air, ſo far as it related to the inſtitution of affinity between the coally principle of the fuel, was probably more hurtful to the carbonation than otherwiſe; but that in ſo far as it haſtened the completion of the affinities, the reduction of quantity, and above all increaſe of produce, though merely as an agent deſtroying the ſuperfluous fuel, it may be conſidered as giving the manufacturer a ſuperiority over his proceſs by means, the extent of which he never could formerly command.

Tradition has, though rather imperfectly, conveyed to us ſome facts which our forefathers ſeemed to have underſtood and practiſed with better effect than their poſterity. In operating with charcoal furnaces, and a blaſt proportioned to the ſcanty means then in uſe for the purpoſe of producing forge pigs, the whole air was conveyed into the furnace by means of a pipe 2, or at moſt 2¼ inches diameter; but when grey metal was wanted, the ſame body of air was divided and introduced by two pipes, whoſe joint capacity was equal to the former.

It appears therefore an enquiry of ſome importance to thoſe embarked in iron founderies, to aſcertain how far this tendency of the fuel to increaſe the carbonaceous principle proceeds in the ratio of the diminution of the blowpipe. If general obſervation confirmed the particulars here ſtated, the effects of carbonation might be greatly increaſed, and the quantity perhaps little reduced, by introducing the ſame quantity of air by means of four, ſix, or eight ſmall pipes, whoſe conjoint areas ſhould be equal to the original column of blaſt.

5. From quantity and denſity of air, there may and do reſult peculiar properties of blaſt, which may affect the operations of the furnace, and which once fully underſtood may help to explain the facts hitherto unaccounted for, and which we before noticed. Facts reſulting from accurate obſervation would prove an invaluable ſource of information upon this ſubject; and it is with regret that we can furniſh no perfect aerological table of the different temperatures of air under different denſities or degrees of compreſſion. The following, we believe, contains the only collection of temperatures hitherto noted; and as it relates to only one degree of compreſſion, the ſatisfaction it affords muſt be only partial.

TABLE of 30 obſervations made in ſummer upon various temperatures of air before and during the act of compreſſion, compared with the thermometer in the ſhade. The air thus aſcertained, was received into a magazine containing 2500 cubical feet, free from moiſture or damp entirely.

Temperature of the air at the lower valves of the blowing cylinder.	Temperature of the air at the upper valves of the blowing cylinder	Temperature of the air ſurrounding the receiving veſſel.	Temperature of the air within the receiving veſſel.	Thermometer in the ſhade at the time of making the obſervations.	Increaſed diff. of temp. between the incloſed air, and average of the two firſt columns.	Increaſed diff. between the incloſed air and the temp. of the external air in the ſhade.
57°	70°	73°	90°	63°	26½°	27°
59	61½	75	87½	64	23	23½
61	71	70½	91	62	25	29
54	68	70	94	66	31	33
57	73	75	95	65½	30	29½
57	72	69	92	64	27½	28
53	70	69	96	64	34½	32
54½	74	70	95½	62	31¼	33
56	68½	71	93	61½	30¾	31½
57	69	73	97½	65	34½	32½
56	70½	70½	91½	64	28¾	27½
52	68	72	88	61	28	27
54	69½	74	86	59	24¼	27
51	71	71	90½	62	29½	28½
57	73	79½	94	64	29	30
55	69	73	93	61½	31	31½
56	72	71½	96	65	32	31
56	72	74	97½	66	32½	31½
53	71	70	99	68	37	31
51	73½	70	98	69	35¾	29
52	75	72	96½	65	33	31½
55	72	73	94	62	30½	32
47	70	76	94	63	36½	31
51	70	77	91	58	30½	33
49	71	75	93	61	33	32
52	74	74½	98	67	35	31
52½	72½	74	101	69	39¾	32
51	73	71	100	74	38	26
54	70	73	102	75	40	27
57	71	74	99½	68	35½	31½

TABLE of 30 obſervations of the ſame nature made in the winter months.

Temperature of the air at the lower valves of the blowing cylinder.	Temperature of the air at the upper valves of the blowing cylinder.	Temperature of the air ſurrounding the receiving veſſel.	Temperature of the air within the receiving veſſel.	Thermometer in the ſhade at the time of making the obſervations.	Increaſed diff. of temp. between the incloſed air, and average of the two firſt columns.	Increaſed diff. between the incloſed air, and the temp. of the external air in the ſhade.
36°	58°	66°	49°	29°	2°	20°
33	54	64	55	30	11½	25
32	51	68	53	29½	11½	23½
33	57	61	50	29	5	21
36	55	60	51½	32	6	19½
31	52	63	50	28	8½	22
29	50	59	48	26	8¼	22
29	49	58	50	27½	11	22½
29	51	59	52	29	12	23
28	50	59	50½	27	11½	23½
30	53½	60	48	28	6¼	20
33	57	61	48	30	3	18
37	56	60	49½	31	3	18½
28	52	62	46	25	6	21
29	51½	59	47	24½	6½	22½
30½	53	59	49	28	6¼	21
33	55	60	53	29	9	24
34	55	60½	56	30	11½	26
32	55	62	54½	27½	11	27
35	56	64	55	30	9½	25
30	50	60	53	30	13	23
27½	50	61	50	28	11½	22
28	50½	62	49	26	9½	23
29	48	58	48	25	9½	23
28	47	58	49	11½	24	25
28½	50	58	47½	8½	21	26½
28	49	60	53	14½	25	28
29	52	61	57	8½	24	27
31½	57	64	55	13¾	26	29
29	54	63	56	15¼	28	27

There can ariſe no doubt but that heat is extricated by compreſſion from atmoſpheric air; and that it is further probable, that the quantity of heat diſengaged is in proportion to its condenſation. If, therefore, we are allowed to reaſon upon this ſubject, we ſhould ſtate the following as a conſiderable approximation towards truth. It is univerſally believed and felt, that combuſtion in the blaſt furnace in June, July, and Auguſt, is conſiderably diminiſhed, as a conſequence of the increaſed temperature of the air. The metal, in theſe months, is frequently debaſed in point of carbonation, and diminiſhed nearly one-half in point of quantity. We ſhall ſuppoſe that this takes place at a temperature of 100, which has been proved to exiſt under a preſſure of 2¼ pounds. The reverſe of this happens in the cool ſeaſon of the year, and particularly in the winter months. The furnace then yields the largeſt quantity of iron, and in the moſt profitable manner. This, with the ſame probability, takes place at a temperature of 50 found in the table.

It would therefore appear to reſult from theſe, that two-thirds, or one-half of the iron only, is manufactured at a temperature of 100, than in winter at 50. The difference between theſe degrees of temperature amounts to 50, and moſt probably in combuſtion affects the operation as ſenſibly as the human frame is affected by a tranſition of temperature equal or ſimilar. It is not neceſſary now to ſtate the difference between ſummer and the denſer air of our winter, the circumſtances of evaporation and aqueous ſolution; theſe ſhall be particularly attended to in the general proceſs of manufacturing iron. The great difference of temperature ariſing ſimply from compreſſion ſeems to us adequate to explain many phenomena regarding the blaſt furnace. Our knowledge, however, upon this ſubject, can only be forwarded by a general collection of facts well aſcertained, ſhewing what are the various degrees of heat made ſenſible by the compreſſion of the blowing machine under every denſity; what the difference in temperature, the denſities being alike, when the air is received over water, in the air-vault, or in the regulating cylinder. From theſe it might moſt probably reſult, that the higher the denſity of the air, the greater would be the degree of heat manifeſted; and it might alſo follow, that in the ratio of this denſity, or temperature, when the air was received over water, ſo would be the evaporation or quantity of water ſuſpended in the air, and of courſe diſcharged into the furnace.

This article may be concluded by the following remarks: —That all iron works are not alike affected by the heat of the ſummer months. Many iron works preſerve the quality of the iron, though at the expence of fuel, and with loſs of quantity; but at other places no extra quantity of fuel will compenſate, either as to quality or quantity, for the want of cool air. Neither ſituation nor denſity of blaſt will explain this curious circumſtance; for with blaſts of equal denſity and quantity, works ſituated not 50 feet above the level of the ſea have been found to manufacture a greater quantity of ſoft iron in ſummer, than at a ſimilar work, not ten miles diſtant, ſituated at leaſt 250 feet higher. At both of theſe works the air is received over water; and no material alteration in the uſe of that air is or can poſſibly be applied. The cauſes of this difference muſt be ſought for in the nature of the coal and iron-ſtone uſed at both works, the inveſtigation of which, however intereſting, would prove a moſt laborious undertaking.

Blast *Furnace*, a large conical or quadrangular building uſed at iron works for ſmelting iron-ſtones and ores.

Blast *Furnace, Deſcription of.*

Plate (*Chemiſtry*) II. *fig.* 1. repreſents a blaſt furnace, and part of the blowing machine conſtructed upon what at one time was the general plan at iron works.

A, the regulating cylinder, eight feet in diameter, and eight feet high. B, the floating piſton loaded with weights proportioned to the power of the machine. C, the valve by which the air is paſſed from the pumping cylinder into the regulator; its length 26 inches, and breadth 11 inches. D, the aperture by which the blaſt is forced into the furnace. Diameter of this range of pipes 18 inches. The wider theſe pipes can be with convenience uſed, the leſs is the friction, and the more powerful are the effects of the blaſt. E, the blowing or pumping cylinder, ſix feet diameter, and nine feet high; travel of the piſton in this cylinder from 5 to 7 feet per ſtroke. F, the blowing piſton, and a view of one of the valves, of which there are ſometimes two, and ſometimes four, diſtributed over the ſurface of the piſton. The area of each is proportioned to the number of valves, commonly they are 12—16. G, a pile of ſolid ſtone building, on which the regulating cylinder reſts, and to which the flanch and ſtilts of the blowing cylinder are attached. H, the ſafety valve, or cock, by the ſimple turning of which the blaſt may be admitted to or ſhut from the furnace, and paſſed off by a collateral tube on the oppoſite ſide. I, the tuyere

by which the blaſt enters the furnace. The termination of the tapered pipe, which approaches the tuyere, receives ſmall pipes of various diameters from two to four inches, called noſe-pipes. Theſe are applied at pleaſure, as the furnace may be deemed to require an alteration in the volume or denſity of the blaſt. K, the bottom of the hearth, two feet ſquare. L, the top of the hearth, two feet ſix inches ſquare. KL, the height of the hearth, ſix feet ſix inches. L, is the bottom of the boſhes, which here terminate of the ſame ſize as the top of the hearth, only the former are round, and the latter ſquare. M, the top of the boſhes, twelve feet diameter, and eight feet of perpendicular height. N, the furnace-top, at which the materials are introduced, or, as it is commonly called, charged; three feet diameter. MN, the internal cavity of the furnace from the top of the boſhes upwards, 30 feet high. NK, total height of the interior of the furnace, or working part, 44½ feet. OO, the lining. This is done in the niceſt manner with fine bricks, from twelve to fourteen inches long, three inches thick, and tapered to ſuit the circle of the cone. PP, a vacancy which is left all round the outſide of the firſt lining; three inches broad. This is ſometimes filled with coke duſt, but more often with ſand firmly compreſſed. This ſpace is allowed for any expanſion which might take place, either by an increaſed volume of the furnace itſelf in heating, or by the preſſure and weight of the materials when deſcending to the furnace bottom. QQ, the ſecond lining, ſimilar to the firſt. The object of this is to guard againſt the entrance of the flame into the maſs of common building, by rents which may take place in the firſt lining OO. R, a caſt-iron lintel, on which the bottom of the arches is ſupported, eight feet and a half long, and ten inches ſquare. RS, the riſe of the tuyere arch, fourteen feet high on the outſide, and eighteen feet wide. VV, the extremes of the hearth ten feet ſquare. This, and the boſhing ſtones, are commonly made from a coarſe-gritted ſand ſtone, whoſe fracture preſents large rounded grains of quartz connected by means of a cement leſs pure.

Fig. 7. repreſents the foundation of the hearth, and a full view of the manner in which the falſe bottom is conſtructed.

AA, the bottom ſtones of the hearth. B, a ſtratum of bedding ſand. CC, paſſages by which the vapour generated from the damps is paſſed off. DD, pillars of brick. The letters in the horizontal view of the ſame figure correſpond to ſimilar letters in the dotted elevation.

Fig. 8. AA, horizontal ſection of the diameter of the boſhes; the lining and vacancy for ſtuffing at M. C, view of the top of the hearth at L.

Fig. 9. Vertical ſide ſection of the hearth and boſhes, ſhewing the tymp and dam-ſtones, and the tymp and dam plates. *a*, the tymp-ſtone; *b*, the tymp-plate, which is wedged firmly to the ſide walls of the hearth; *c*, dam-ſtone, which occupies the whole breadth at the bottom of the hearth, excepting about ſix inches, which, when the furnace is at work, is filled every caſt with a ſtrong binding ſand. This ſtone is ſurmounted by an iron plate of a conſiderable thickneſs, and a peculiar ſhape, *d*; and from this it is called the dam-plate. The top of the dam-ſtone, or rather the notch of the dam-plate, is from four to eight inches under the level of the tuyere-hole. The ſpace under the tymp plate, for five or ſix inches down, is rammed every caſt full of ſtrong loamy earth, and ſometimes even with fine clay. This is called the tymp ſtopping.

The ſquare of the baſe of this furnace is 38 feet. The extreme height, from the falſe bottom to the top of the crater, meaſures 55 feet.

Blast *Furnaces, Conſtruction of.*

Theſe furnaces are ſometimes built of an external quadrangular form, entirely of ſand ſtone, and lined, in contact with the fire, of the ſame materials; ſometimes they are built conical, entirely of bricks, or with ſand ſtone on the outſide, and linings of both common and fine bricks within.

One great deſideratum in the conſtruction of furnaces, is to counteract the effects of a powerful expanſion, which always take place, to a greater or leſs extent, after heating, and the introduction of the blaſt, and which has frequently proved fatal to the exiſtence of the entire fabric.

In the general ſtyle of building, all are agreed that the pillars, which ſupport the arches, and of courſe the whole fabric, ought to be done in the moſt ſubſtantial manner. But beyond the arches, a variety of methods has been adopted to enſure a complete fabric, free from large openings or rents after a few weeks blowing.

Some iron-maſters are of opinion, that the ſame degree of firm building, that is beſtowed upon the pillars, ought to be continued to the top, with the addition of binders of flat iron preſſing with their edges againſt the body of the building, or with four ſcrewed bars, ſtill paſſing through the external building, and forming one ſquare binder, if the ſhape of the furnace is quadrangular. Another ſpecies of binder is uſed for ſquare piles, made of caſt iron of a prodigious ſtrength and weight. The individual pieces forming this binder, have, at their extremities, mortiſes, which mutually receive each other, with a conſiderable extra ſpace for the expanſion, which is invariably experienced afterwards. Other iron-maſters, again, prefer rearing a ſubſtantial ſhell of building, and filling the interior ſpace towards the linings, either with dry bricks, or ſtones looſely laid together. When the maſs of building becomes thoroughly heated by the kindling of the fire, and the introduction of the blaſt, the interior of the furnace expands conſiderably, and the action is ſuppoſed to be merely confined to the wedging together of the looſe parts of the building. By the time that this is effected, the expanſion is ſuppoſed to have ceaſed, and the exterior ſhell of the furnace is preſerved entire. Others, equally anxious to form a perfect building, have given an octagonal form to that part of the furnace above the arches, that the binding might be more happily effected. Some have aſſumed this form, with the addition of ſemi-circular receſſes in the ſides of the octagon; their convexes being ſtrongly arched to reſiſt the powerful preſſure expected from within.

Still more determined to defy the all-powerful effects of expanſion, others have hollowed furnaces from the ſolid rock, forty to fifty feet high, and lined theſe immenſe perforations with fine bricks in the uſual form.

Where ſuch a variety of form and of method exiſts in effecting the ſame purpoſe, and where the inſtances of experiment have been very numerous, every mode of conſtruction can boaſt of a ſolitary inſtance of complete ſucceſs, excepting in the caſe of the rock, which was only once attempted, and which, after the introduction of the blaſt, opened from four to ſix inches from top to bottom.

There are ſo many circumſtances to be taken into the account, beſides the mere form of the building, that unleſs theſe are all equally guarded againſt, the chances are in favour of the furnace opening conſiderably. If the building is conſtructed of ſand ſtone, and if this material is carried from the quarry as it is wanted by the workmen, an immenſe proportion of water is thus introduced, which by a little foreſight might have been avoided. Sand ſtones of common denſity as to fracture, contain, when taken immediately from the quarry,

from 8 to 10 per cent. of water, and coarser gritted stones from 10 to 12. Taking the average 10 per cent., then in a furnace of equal dimensions to the drawing in *Plate* II. *fig*. 6. the sand stone of which will weigh upwards of 1200 tons, there will be introduced 120 tons of moisture. This quantity is always considerably increased by the portion of water necessary to reduce the lime to mortar, and frequently augmented by the moist state of the weather during building.

The evaporation of this immense body of water is the source of all the mischief which takes place in the shell of the blast furnace; nor is it much to be wondered at, where every precaution is not used to bring the heat forward in the most gradual manner, preserving the clearness of the vents, and allowing the moisture insensibly to pass away?

In situations where bricks can be obtained, the moisture of the sand stone is avoided, but the great extra quantity of lime, which is necessary to build with bricks, introduces through the medium of the mortar an almost equal quantity of water, as with sand stone. This has been obviated in part by using soft clay in the interior of the walls; but as clay seldom binds to any great extent, the general push of the furnace must be trusted to good binders from without.

In the construction of all blast furnaces, a complete ventage ought to be preserved by means of narrow flues, or passages proceeding horizontally from the middle of the solid shell, or within two feet and a half of the interior to the outside. These ought to be connected with a circular channel, or gutter, of the same dimensions, proceeding round the circumference of the furnace; so that if any one vent were choaked in the general expansion, the moisture conducted by it might easily vent itself among the other openings. The vents cannot well be too numerous; and as they seldom exceed four inches square, the building cannot be materially weakened by them.

In addition to the horizontal channel of communication, some builders carry up in the main building of the furnace four, six, or even eight perpendicular flues, which communicate with it and the openings that proceed horizontally to meet the external air. See *Plate* VIII. *figs*. 1, 2, 3, 4.

Either of these methods may be considered as just precautions to insure the existence of the furnace, but adopting them in the fullest and most complete manner, is not always accompanied with similar success. If circumstances formerly noticed concur in occasioning an extra degree of expansion, the pressure of the lining against the common building of the furnace often deranges the systematic order of the vents, pushes the bricks into contact with each other, and smothers for a little while, though to gain more fatal elastic effects, the increasing volume of the vapour.

After such a diversity of opinion upon a subject of such general importance, wherein each respective class of votaries can boast of complete success from its peculiar plan, it may be difficult to point out one more generally attended with good effects than another. The following, however, may deserve the serious consideration of the manufacturer of pig-iron.

Of whatever materials the furnace is constructed, let them possess no more moisture than is sufficient for their proper building. The thickness of the common building not to exceed, at its greatest breadth, 6½, or 7 feet. In the middle of the wall, a space of four or six inches ought to be left clear all the way to the furnace top. Into this vacuity should be introduced small fragments of sand-stone, about the size of an egg and under. When the expansion, proceeding from the fire building of the interior, causes the bricks immediately in contact to push outwards, the masses of sand-stone are immediately reduced in size, and filling the interstices occasioned by their former angular shape, actually occupy much less room; and now present to the flame or fire, should it be inclined to penetrate so far, a solid vertical stratum of sand, after having secured the expansion of the furnace to the extent of some inches. The effects of the pressure are thus diverted from the shell of the building, and lost in the pulverization of the fragments of sand stone.

The advantages resulting from this plan may be nearly doubled, by using a double lining of fire bricks, as represented in *Plate* VIII. *fig*. 3. betwixt each of which, and the common building, a similar vacancy should be left; but filled with sharp sand, containing no more moisture than serves to compact it into a firm body. As this moisture becomes gradually expelled in the slow heating or annealing of the furnace, the sand occupies less bulk, or, which is the same in effect, is then susceptible of a greater degree of compression when the general expansion of the furnace comes on. It is evident that the force is here also diverted against the sand in place of acting immediately, with a tendency to enlarge the circumference of the building.

Over and above all these precautions, the annealing or drying of the furnace in a progressive and regular manner ought to be carefully attended to and continued for two or three months at least. Many are blown much earlier, from an anxiety to get to work, and make returns for the great capital necessarily expended in these undertakings.

The same variety of opinions exists in the trade relative to the determined figure and dimensions of the blast furnace, as subsist, with regard to the best mode of building. Its height has, at different times, varied from 20 to 70 feet; and its diameter, at the boshes, or widest part, from 8 to 15 feet. It will be easy to trace the source of this indefinite mode of construction, and the uncertainty which must necessarily pervade operations of so much risk and importance.

At the time when charcoal of wood was the common, and indeed, the only fuel used in the blast furnace, the volume and extent of the blast were proportioned to the very imperfect state of the blowing machinery. Long experience had taught the manufacturer what were the proper size and dimensions of his furnace. Many of them were from 12 to 18 feet high, and some of them, where a good water wheel blast existed, reached as far as 28 feet in height.

When pitcoal was introduced into the blast furnace, in the state of coke, to produce similar effects to the charcoal of wood, it was soon found, that in furnaces of equal capacity and height the same effects could not be produced. The ore required to remain in contact with the ignited fuel for a longer space of time, in order, unquestionably, to produce, by attenuated contact, what was deficient in temperature, for the saturation of the ore with coaly matter. This would immediately suggest an increase of the height of the blast-furnace; and if beneficial effects once resulted from a step of this nature, it became a matter of difficulty to say where the progression of height would stop.

Hence, in a few years, arose furnaces of 40, 50, 60, and 70 feet in height. Of the last dimensions, one was erected in Wales. The size of the artificial crater was such, that the strength of the blast was scarcely sufficient to keep the existence of flame visible at the furnace top. After in vain endeavouring to ignite the immense body of materials contained in its vast capacity, the height of the furnace was reduced 30 feet by cutting a hole in its side, narrowing the mouth, and throwing in the materials at the height of 40, in place of 70, feet from the furnace bottom. This was at-

tended with succeſs, and the opertions of the furnace proceeded with their uſual facility.

After the application of ſteam engines to raiſe and condenſe air, the quantity and ſtrength of the blaſt became more a mechanical property in the hands of the manufacturer. It was ſoon diſcovered that an increaſed volume of air, by exciting a much higher temperature throughout the furnace, conſtituted the immediate action of thoſe affinities, which the tall furnace accompliſhed by a long attenuated contact, and that iron equally carbonated and fitted for the purpoſe of melting, could be produced by 30 hours contact, as in four days.

The conſequence of theſe gradual diſcoveries was a general predilection in favour of ſmall furnaces, and at preſent the bias of the manufacturer ſeems inclined to this extreme. Where the maximum will be found it is difficult to conjecture, for the ground which the manufacturer now occupies is materially altered from what it was when ſmelting with coke was firſt introduced. The perfection to which the blowing machine has attained, forms a ſtriking contraſt to the feeble and diminiſhed effects of the bellows in the infancy of the trade. So far as the neceſſary affinity is increaſed, and more inſtantaneouſly produced in high temperatures, than in thoſe inferior, the manufacturer is differently circumſtanced, and commands an extent of means unknown to him in former times. That this ſuperiority will produce equivalent effects in the modification of the blaſt-furnace, requires but little demonſtration. Two facts illuſtrative of this may, however, be mentioned. Caſt ſteel has of late years been formed directly from bar-iron, by a proceſs which only requires an hour or two to complete, and with ſmall quantities of matter the ſame may be performed in a few minutes. This is effected by preſenting the carbonaceous matter to the iron at a melting temperature. In the uſual mode of cementation, bliſtered ſteel, by a more attenuated contact and inferior temperature, requires ſix or ſeven days to complete, what is here produced in two hours. The difference of temperature in the two operations is equal to 60° or 70° of Wedgewood. The firſt operation will be conſiderably ſhortened, if the caſt ſteel is required to hold much carbon; but if this requiſite is neceſſary in the bliſtered ſteel, the length of the cementation muſt neceſſarily be protracted. Again, a piece of malleable iron may, by preſenting it with a proper doſe of carbon, at a high temperature, be converted, in a few minutes, into a maſs of the richeſt carburated caſt-iron, which, in a temperature inferior, would have required ſeveral months.

The ſame facts will apply, in part, to the manufacture of pig-iron in the blaſt-furnace; but an unanimity of opinion and action on this ſubject is precluded, as well by the prejudices of individuals, as from circumſtances ariſing out of the nature of the materials operated upon in different places.

A furnace has lately been tried at Muirkirk in Scotland, only eight feet diameter acroſs the boſhes, in place of its former dimenſions, which were ten feet, and 40 feet high. It was ſoon found, that with the ſame volume of blaſt which was formerly applied to the ten feet furnace, very inferior effects were now produced. The combuſtion apparently was carried to too great an extent, and the materials, owing to this circumſtance, entered into fuſion before the iron had imbibed a ſufficient doſe of the coally principle from the fuel. Another great evil which reſulted from this diminution of diameter, was a friction, or retardation of the deſcent of the materials upon the lining of the furnace. This evil was increaſed and the materials made more bouyant, by the uſual volume of air elevating itſelf in a cone not much more than half its former area. The conſequences were, that the whole mixture of coke, iron-ſtone, and lime-ſtone, would have frequently hung for an hour together, or until the blaſt had cut all the hearth and boſhes clear of materials, a ſlip would have then enſued, and brought with it a large proportion of newly introduced matter. The introduction of this into the fuſing point before being properly heated, and long before any affinity had been eſtabliſhed betwixt the particles of metal and the carbon of the furnace, invariably changed the quality of the metal, and cauſed frequent and ſudden alterations from grey to white iron.

Upon the ſubject of height and width of blaſt-furnaces, it may be finally remarked, that the average height in Britain may be taken at forty feet from the upper ſurface of the hearth bottom, eleven feet diameter at the greateſt width or boſhings, and three feet and a half for the diameter of the tunnel-head, or furnace-mouth.

If the proportions of height and diameter in the dimenſions of the blaſt-furnace have given riſe to a multiplicity of opinions, the internal ſtructure and ſhape of the cavity have been no leſs an ample field for ſpeculation and prejudice. At one time this was conceived ſo eſſential to the ſucceſs of iron-making, that any particular furnace that had made a fortunate run of quantity and quality, was copied with the greateſt accuracy of deſign. The fortunate iron-maſter ingeniouſly attributed to the mechaniſm of his own conſtruction the rich and ſuperior harveſt he had reaped in metal, and ſaw, or fancied he ſaw, in the curvature of a line, or in the inclination of a ſlope, the taliſman of his good fortune. By prolonging the one, or depreſſing the other, he immediately inferred that ſtill ſuperior effects would be produced, and that by obtaining the perfection of art in the mere fabrication of ſtructure, every thing that was great and powerful would enſue. This rage continued for many years, and gave riſe to an endleſs variety of ſhapes, many of which, in their eventual ſucceſs, had only the merit of originality to boaſt.

In the eſtabliſhment of this important and national manufacture, the great fluctuation of opinion as to ſtructure ſeems to have been the prelude to a ſubſidence into approved forms, founded upon general principles; and though we may now ſmile at the indiſpenſible forms which our predeceſſors, or even contemporaries, annexed to the blaſt-furnace, yet theſe alterations of ſhape and ſtructure lay the ſtrongeſt claim to our reſpect and gratitude. The path is now opened, and the ground already beat; from the labours of thoſe who have already gone before us, reſult the happieſt effects; we proceed towards our object, free from the interruption which inexperience always entails; and we may now, by the direct application of principle, perfect with facility what may ſtill be deemed deſiderata in this important branch.

The varieties of ſhape which cuſtom and experiment, from time to time, had annexed to the blaſt-furnace, may be claſſed under four diſtinct kinds. *Plate* VII. and VIII. The following deſcription, characteriſing the reſulting properties and dimenſions in the form of each claſs, will be neceſſary for comprehending the ſubject thoroughly.

Plate VII. *fig.* 1. is the vertical ſection of the blaſt-furnace cut acroſs the top of the boſhes; the internal ſhape entirely conical; the external figure a quadrangular pyramid. The conſtruction of this furnace is truly ſingular; and from this alone great advantages were expected to reſult. The originality of the principle conſiſts in the double ſquare, or throat. One immediately above the hearth, not repreſented in this figure, but ſimilar to the ſquare in *Plate* IX. *fig.* 1. B; and another half way up the cone, four feet in diameter; ſee A.

B, the top of the boſhes, 12 feet in diameter.

C, an inferior diameter of 10 feet, previous to the formation of the throat at A.

D, the top of the ſecond row of boſhes, of the ſame diameter as B.

E, the furnace mouth, or termination of the ſecond cone, four feet diameter, and proportioned to A.

F, funnel top for carrying off the flame occaſioned by the blaſt, ſo as not to interfere with the workmen in filling the furnace.

The dimenſions, as to height, are as follow:

From B to C	height - - - - -	12 feet
C to A	ditto - - - - -	6
A to D	ditto - - - - -	6
D to E	ditto - - - - -	13
Height of the hearth, and firſt row of boſhings, not ſhewn in the figure, but being the ſame as *fig.* 1. *Plate* IX. meaſure	- -	15
Height of the bottom ſtones, packing, and falſe bottoms,	- - - - - -	4
Total height of this furnace from the foundation		56 feet

GG, fire brick lining.

hh, ſpace left for packing.

II, the common building either of ſand-ſtone, or of bricks.

Fig. 2. plan and ſection of the ſame furnace taken acroſs the boſhes at B.

AAAA, ſquare of the common building 29 feet upon the ſide, bound by BBBBBBBB, eight caſt-iron binders; the number or ſetts of theſe requiſite, being proportioned, both in ſtrength and dimenſions, to the height of the furnace. In common, a full binder is applied every ſix feet in the height.

The concentric circles repreſent the various diameters of the interior of the furnace, and are connected each by dotted lines, with their reſpective places in the elevation.

The reaſoning which we believe led to the conſtruction of this furnace, proceeded from a firm belief that the boſhes and throat or ſquare of a blaſt-furnace were of the greateſt importance on two accounts. Firſt, becauſe they ſupported the weight of the materials; and ſecondly, becauſe they concentrated the heat. Theſe acting conjointly, permitted the leaſt poſſible quantity of materials to paſs, till they dropt away in a ſtate of ſemi-fuſion, or complete ſeparation. In furnaces, however, the cones of which were 30 feet high and upwards, this was conceived impoſſible to take place for any length of time, to any conſiderable extent. The height and gravitating preſſure of the materials were more than ſufficient to counteract the moſt favourable conſtruction of boſhes; and as this could not admit of diminution, the ſuſpenſion of the materials, and the concentration of the heat muſt be effected by ſome other means. This, at one time, was believed to have been completely effected by the ſcheme of an additional ſquare, and an extra ſet of boſhes; and there is little doubt but that, by converting perpendicular to lateral preſſure, the ſuſpenſion of the materials was reduced at leaſt to one half of its former intenſity.

It was not doubted but that the proceſs of ſmelting and ſeparation would commence, in part, at A; that what eſcaped fuſion and ſeparation in that quarter, would be eaſily reſolved below; and that the proceſs of combuſtion intenſely at work in two different places at once, would greatly facilitate the general reduction, and add greatly to the produce in iron of the furnace. Theſe ſanguine expectations were unfortunately never realized, the ſolitary inſtance of one furnace only being conſtructed in defence of this theory, and that only for a very temporary endurance, is the beſt proof of the inutility of the plan.

Fig. 3. is the elevated ſection of a blaſt-furnace, of which ſeveral were built, and from which it was at one time conceived that the greateſt advantages were derived. The numerous minute gradations of diameter exhibited in the conſtruction of this furnace, were at one time held in high eſtimation by many iron-makers; and a plan of the preſent furnace circulated from the domains of the lucky projector, with as much care and conſciouſneſs of rich acquiſition, as an antiquary would remove from Herculaneum or Egypt, the precious remains of antiquated obſcurity.

It will be extremely eaſy to trace to its ſource this particular bias to form, ſo univerſally believed in at one time, but now conſigned to that oblivion which experience has taught us it deſerved at a much earlier period.

It often happens, that when repairing or re-lining a blaſt-furnace, the manufacturer avails himſelf of the time thus obtained, to overhaul and repair his engine and blowing machine. The former movements of the machinery may have diſcovered to him many errors both in movement and conſtruction, which the conſtant requiſite motion rendered impracticable for him ſooner to remove. In this way, conſiderable improvements on the engine and blowing apparatus are frequently made; and when again in motion, may, by increaſing the length and number of the ſtrokes in a given time, or by conferring a higher additional working power on the ſteam piſton, increaſe at the ſame time both the volume and denſity of the blaſt. If the produce of the furnace is increaſed, which it is highly probable will be the caſe, then the ſuperior effects are attributed to a few unimportant circles and lines added to the interior of the cone, the acuteneſs and proportion of which do not ſurvive the blowing of the furnace three days.

In like manner, if a work entirely new, commence operations with a greater advantage of blowing power, and with ſomething original in the ſhape of the furnace, the conſequent effects of the former are induſtriouſly attributed to the fortunate conſtruction of the latter, and the grand eſſential blaſt is entirely overlooked, and its next important aſſociates coal and iron-ſtone.

The dimenſions of the preſent furnace are as follow:

Diameter of the cone	at A	- - - -	3 feet
ditto	at B	- - - -	4
ditto	at C	- - - -	$8\frac{1}{2}$
ditto	at D	- - - -	$9\frac{1}{2}$
ditto	at E	- - - -	10
ditto	at F	- - - -	11
ditto	at G	- - - -	10

From G to F, the diſtance in height meaſures		1 foot
Increaſe of diameter -	1 foot	
F to E, the diſtance is -		12
Diminution of diameter -	1 foot	
E to D, the diſtance is -		$1\frac{1}{2}$
Diminution of diameter -	6 inches	
D to C, the diſtance is -		6
Diminution of diameter -	1 foot	
C to B, the diſtance is - -		2
Diminution of diameter -	$4\frac{1}{2}$	
B to A, the diſtance is - -		$4\frac{1}{2}$
Diminution of diameter -	1	
Height of the hearth and boſhes not repreſented in the plate - - -		13
Total height of the cavity of the furnace or place occupied by the materials -		40 feet

The former deſcriptions will ſuffice and apply to this

plate, with equal propriety as to the former, regarding the lining, packing, common building, &c.

Fig. 4. is a plan and fection of the fame furnace at F in the elevation.

The inner circles reprefent the various diameters of the interior of the cone, the letters in each correfponding. The two external circles defcribe the packing and lining; and the circle N exhibits the circumference of the common building of the furnace, which, at this particular fection, is 26 feet in diameter.

Plate VIII. *fig.* 1. is the elevation of the interior of a furnace of a plain conftruction, and at one time very prevalent at founderies. This fafhion was deemed to poffefs its peculiar merits, and ftill maintains its form unaltered at fome iron-works where the regular tapering cone is not yet admitted. Its inferiority, as to height, is amply made up by an enlarged capacity arifing from its diameter.

Diameter at the mouth of the cone	A	-	3 feet
ditto - at	B	-	11
ditto at the bofhes	C	-	12

Height from C to B - -	12 feet
from B to A - -	14
Height of the bofhings and hearth not reprefented in the figure - -	
Total height of that part of the furnace occupied by the materials	37 feet

FF, reprefents a view of the vertical method of carrying off the moifture and fteam from the mafs of building, by means of vents. The number of upright flues vary from four to eight, and have regular communications by means of horizontal openings with the external air, GG. They are generally carried up parallel to the lining, and incline with the general diminution of the cone. The former, or vertical openings, are fix inches fquare, and the horizontal communications four inches fquare.

Fig. 2. is a plan and fection of *fig.* 1. in which are reprefented the lining, the vacuity for packing, and eight vents or openings correfponding to thofe in the elevation. The letters in each figure correfpond, and the two dotted circles are meant to fhew, that occafionally all the vents communicate with each other by means of a horizontal gutter, or channel, carried quite round the building. This precaution is ufed left any of the tubes were to fill up and choak the free circulation of the vapour, that its appropriate quantity may get eafily difcharged amongft the other openings.

Fig. 3. is an elevated fection of a furnace, the interior fhape of which has now almoft become univerfal. The regular and uniform defcent of the materials which follows, as a confequence of the gradual enlargement of the cone, fully juftifies the general partiality in favour of this fhape.

Diameter at the mouth, or opening A -	3 feet
Diameter at the top of the bofhes B -	10
The height from B to A - - - -	$31\frac{1}{2}$
Height of the hearth and bofhes not feen in the plate - - - - -	$11\frac{1}{2}$
Total height of this furnace -	43 feet

This form of furnace is not only conftructed with a double lining of fire bricks CCCC, and two openings for introducing fand for packing *bbbb*, but has alfo an opening DD, from top to bottom, about the centre of the common building. From this, in all directions, proceed fmall vents, which communicate at a fhort diftance with the open air, as may be feen along the fides of the building.

Fig. 4. is a plan and fection of *fig.* 3. cut acrofs at B.

B, diameter over at the bofhes 10 feet.

CCCC, the two circles of fire brick-lining, as feen in the elevation.

bbbb, fpaces for receiving packing.

DD, circular vent, or general gutter, from which ramify the horizontal openings.

Thefe are repeated at intervals of four feet in the height, as may be feen in the elevation. In building, DD is filled with fragments of foft fand-ftone, which are eafily reduced in the expanfion of the furnace, and tend, by diverting its real preffure, to preferve the body of the building entire.

A fimilar want of unanimity of opinion fubfifts among iron-makers, relative to the general conftruction of the bofhes, their particular height, and moft beneficial range. Some contend for flat, others for bofhes more vertical, while others again conceive the exertions of thofe equally fuccefsful, who adopt the mean of the two extremes. At different places, and to every poffible range, have been atributed the moft important confequences in the fubfequent procefs.

Plate IX. *fig.* 1. reprefents bofhes of the fteepeft conftruction.

Diameter at A - - -	10 feet
Perpendicular height from B to A -	8
Square at - - B - -	$2\frac{1}{2}$

The opinion relative to this form is, that at firft blowing, the bofhes are productive of a very proper degree of fufpenfion of the materials; but as the preffure of the defcent bears in every direction upon the under or bottom part next the fquare at B, it becomes increafed fo much, that the weight of the incumbent materials early begin to prefs too much towards the bottom of the hearth, counteract the regular precipitation which fhould take place, and impede the afcent and full effect of the blaft.

Fig. 4, is a fection of bofhes approaching to, or indeed may be confidered as the oppofite extreme. Here the reverfe of the fact attributable to N° 1. takes place. The preffure of the defcending material is equally diftributed over the very flat inclination of the bofhes, and there is no more weight deemed to be on the fquare at A than is equal to a full column of the materials of fimilar dimenfions, left by the direct tendency which the ftrength of the blaft to keep them in a ftate of partial buoyancy. To counteract thefe advantages in part, very ferious defects are here alfo imputed. If circumftances unite to increafe the tear and wear at A in any uncommon ratio, either by *fcouring*, or from a deficiency in the quality of the ftone or bricks, the whole of the upper part of the hearth at B B is immediately expofed, and, though compofed of a fuperior quality of fand, will foon follow the direction of the defcending current. A preffure of materials then takes place, equal to the whole of the increafed fpace, while the effect of the blaft to bear them up is confiderably diminifhed by the enlargement of the original diameter. It will be feen from the plate that the weaknefs of flat bofhes at the top is ill calculated to withftand any accumulating preffure, and that by confining their part of the procefs to the hearth, the latter muft foon, by a fimilar widening, be entirely deftroyed.

Thofe who wifh to fteer clear of extremes, or profit by the more adventurous fpirit of their neighbours, more generally adopt a mode of bofhing that occupies the mean of the two former extremes. This is reprefented by *fig.* 3.

Diameter of the bofhes at A - - - -	10 feet
Perpendicular height from B to A - -	5
Diameter of the fquare B - - -	$2\frac{1}{2}$

In general, the bofhes of blaft furnaces are made of the fame fand ftone with the hearths, but of late fire bricks have been introduced with a confiderable indication of advantage.

and permanency. When bricks are used, it is found of utility to make the whole part of the building solid, back as far as the external square of the hearth, so that if the boshes fail in part as to displace one layer of bricks, another surface, equally fresh and entire as the former, presents itself to the action of the fire.

Fig. 2. Ground plan of the top of the boshings of *fig.* 1. A A and B correspond to the same letters in the elevation. The dotted square C describes the form and dimensions of that part of the hearth immediately above the tuyere, as seen in the elevation CC. The large dotted square DD is the external size of the hearth, as seen also in the elevation DD.

Fig. 5. Ground plan of the square and boshings of *fig.* 4.

While we prosecute the detail and history of the construction of the blast furnace, the same diversity of plans formerly noticed comes under review, in every department of the erection. The importance of the hearth is admitted by every class of reasoners upon this subject; and to devise a form better calculated for smelting than another, has been an object of general concern with the manufacturer. Much as may be deemed to depend upon its form and construction, infinitely more benefit is derived from a proper quality of stone, to resist for a given length of time the powerful effects of a continued and unremitting blast. To both of these important desiderata much of the manufacturer's attention has been from time to time directed.

The first singularity that strikes us forcibly in the figure of the hearth, is, that in place of being circular, like the upper parts of the furnace, it is constructed of a square funnel-form, with angles as acute as represented in *Plate* IX. *fig.* 1. This narrowing form is continued on three sides of the square to the bottom of the hearth, where it generally measures from 22 inches to 24 inches. The top of the hearth, at B or A, *fig.* 1. and 4. or as it is commonly called the square, is never less than 30 inches, nor more than 33. The height of the hearth from E to B, *Plate* IX. *fig.* 1, 7 feet, and none are made higher. From C to B, *fig.* 3, 6½ feet, which is now reckoned the most advantageous height; and from C to A, *fig.* 4, the hearth measures 6 feet, under which height there are no hearths ever attempted.

The structure of a hearth, properly speaking, consists of three solid sides only, the fourth, or front, is filled up by the tymp, or key-stone. *Plate* IX. *fig.* 1. The block E. is generally in one piece, and from four to five feet long, according to the height of the hearth. It descends towards the bottom till within two feet or two feet four inches, and then leaves an opening of similar dimensions, as to height, into the centre of the hearth or funnel, as at letter F.

As the square form in which the hearth is finished cannot last a day after the blast is introduced, and is even frequently destroyed in the act of annealing, or heating, it cannot be essentially necessary to the making of iron. The hearths of all furnaces when blown out, are entirely round, or if wasted more upon the tuyere sides, oval. The general usage of the square must have been derived from long acquired habit, or perhaps from the conveniency of working and finishing those immense blocks of stone which are still deemed necessary to the perfection of a hearth. The interior of charcoal of wood furnaces was at one time entirely square from top to bottom, so that in the progress of the trade, from smelting with wood to the use of pit-coal, although the general shape of the furnace has been altered, the square figure of the hearth has been retained.

Whatever may have been the utility of this general predilection in favour of established forms, the advantages hitherto supposed to be derived from this source are now by many doubted, and all those nice speculations relative to the precise dimensions and figure of boshes and squares, threatened with total annihilation. This innovation is not confined to figure alone, but extends to dimensions, and to the nature and bulk of the material necessary for the construction of hearths.

Fig. 1. *Plate* X. is the section of a hearth and boshings, constructed upon an enlarged principle as to size.

Diameter of the boshes at A	- -	10 feet
Diameter of the hearth at B	- -	4
Diameter of the hearth at C	- -	3

These enlarged dimensions, in place of being square as formerly constructed, are now entirely round, excepting where the tymp stone forms the key to the front of the hearth, as may be seen in *Plate* X. *fig.* 2. where the external circle A A represents the diameter of the boshes, B, the termination of them, or the top of the hearth, and the form at C, a plan of the inside figure of the hearth across the bottom of the hearth at C, *fig.* 1. same plate.

The difficulty of always obtaining a sand-stone well calculated to stand the violent effects of the blast, the frequent great expence incurred, the immense loss of time sustained in cutting out old and putting in new hearths, and afterwards annealing them, has induced more masters to speculate upon the use of bricks of shapes larger than the common forms, made from good fire clay. No permanent advantage has hitherto been derived from this scheme, although it is abundantly obvious, that a successful experiment of this kind would lessen the expence of a hearth greatly, and save at least half the time now required to replace an old one.

Neither have any uncommon advantages resulted from the hearths laid down in *Plate* IX. *fig.* 6. and in *Plate* X. *fig.* 1, 2, and 3. While some approve, more are ready to condemn a measure, which has for its object the enlargement of a space before blowing, which too speedily becomes so afterwards. There cannot, however, be any objection to the circular, in place of the square form, unless a little additional workmanship is sustained as such. The matter rests with experience, accompanied by accurate observation, to prove the sanguine hopes of the projectors, or falsify the prophetic forebodings of those who now condemn the measure. The amount of our progress hitherto, in the making of pig-iron, is ascertained with certainty; to assign limits to its ultimate bounds would be presumption. Of one fact, however, we may rest assured, that the perfection of the steam engine, and the consequent command of blast, has alone done more for the manufacture of this article, than all those nice shades of distinction as to furnace taken collectively, which relieve each other in a successive train of minute gradation from one extreme to the other; to all, or to most of which, the most wonderful effects have been from time to time ascribed.

One subject of consid rable importance still remains to be discussed, relative to the construction of the blast furnace; namely, the absolute and relative heights of the tuyeres, the dam-stone, and tymp.

On the subject of tuyeres, the general opinion is, that the nearer the cinder the blast is introduced, the greater is the effect as to the absolute quantity of reduction. But this may be productive of consequences more than sufficient to counterbalance the doubtful advantage of accelerated reduction, either by blowing the cinder from off the surface of the iron, and de-carbonating it, or by the cinder rushing back through the blow-pipe at any stop of the blowing machine, and destroying the leather bag which connects the blow-pipe with the main laying pipes. This never

happens but a considerable portion of time is sacrificed, besides the expence of the bag.

In common, the surface of the tuyere plate is laid eight inches above the cinder, or, which is the same thing, above the level of the dam-stone. Some blow at a distance of four inches, others at six and eight, and some again as high as twelve and fourteen inches. However, under some circumstances, the height of the tuyere is determined by the nature of the materials. In these cases, if the tuyere is only raised one inch above its proper height, the bottom of the furnace lumps up immediately, and will invariably rise in the same progressive manner in which the tuyere is heightened.

Plate X. *fig.* 1. represents the relative proportions of height betwixt the dam, tuyere, and tymp, in ordinary cases.

G, the dam, or notch of the dam plate, 17 inches above the level of the bottom at H.

I, the centre of the tuyere 26½ inches from the surface of the bottom, and 9½ inches above the level of the dam.

K, the bottom of the tymp plate, 23 inches from the bottom of the furnace, and 6 inches above the level of the dam.

At iron-works where different opinions exist as to the proper or working height of the dam, very different relative heights ensue, regarding the tymp and tuyere. The former should always regulate the other two. The height of it is seldom used less than 16 inches, nor more than 28 above the bottom.

Considerable advantages result from placing the tuyere, as to its horizontal position, at a judicious distance from the front or back wall. This is, as in the case of height, often regulated by the nature of the materials. If the furnace, owing to this circumstance, tends to work cold and languid behind, with a propensity to lump at the back wall, the blow pipe ought to be directed as near to the extremity of the hearth backwards as it is possible to get in the tuyere iron; *Fig.* 4. *Plate* X. letter *a*: but where the operations of the furnaces proceed with ease and facility, the centre of the tuyere should more generally approach the centre of the hearth, as at *b*.

Of late years a new mode of blowing has been introduced, which, from its great prevalency and good effects, seems to bid fair to come into general use. Furnaces till lately were only erected with one arch, or tuyere side, and the blast or column of air introduced by means of one blow pipe; now most of the new furnaces are built with double tuyeres, with two sets of main conducting pipes, and the blast introduced by means of two pipes in place of one.

The general effects and supposed properties of this mode of blowing are attended to under the article blast.

In the mean time, the proper height and distance of the tuyeres, and their relative position to each other, have been subject to endless disputation. *Fig.* 4. *Plate* X. *a* and *b* shew how, in common cases, the tuyeres are placed to each other in their horizontal range: *a* is placed with its centre three inches from the extremity or back wall of the furnace, and *b* at the distance of nine inches from its centre. That there should be a difference of distance in their horizontal position none are inclined to dispute; but that this should take place in their vertical situation, is by some contended; while others insist that the difference ought never to be less than four inches. *Fig.* 6. *Plate* IX. *e e*.

Some less fastidious assert, and with many evidences of sound reasoning on their side, that if the blast is introduced into the furnace, and at a proper distance, to keep the back wall clear, those nice distinctions as to inches go for nothing, in a region where an instantaneous increase of volume must destroy all repulsion or mechanical contact. This philosophical reason is flatly denied, and the contrary minutely and gravely asserted, that were two pipes placed every way immediately opposite to each other, the action of the opposite columns would retard the velocity of the air, and diminish the real elevated quantity in the furnace, by locking up in mutual opposition a portion of their respective quantities in the laying pipes. There might be some foundation for this conjecture, were the respective nozles or blow pipes brought into actual contact, or inserted into each other; but to those who consider, that in most furnaces there is never less than four feet of distance between nozle and nozle, and the most of the intervening space filled with a column of semifused materials, ignited to the highest pitch of whiteness, this supposition will appear to rest upon very unsatisfactory grounds.

A less scrupulous class of observers and reasoners upon this subject even go the length to assert, that the tuyeres ought to be put in direct opposition, and that this, so far from being detrimental, would be found to possess unqualified advantages. This it is said would result from a certain degree of coolness which the extremity of each column of air confers upon its opposite tuyere iron, and prevent the same from heating and burning. To whatever cause it is attributable, the fact stands in many instances unquestioned, that not half the tuyeres are lost or burnt out, with the double blast, that was formerly destroyed, where the single blast was in use.

Fig. 7. *Plate* X. represents a tuyere iron, 16 inches wide, and 12 inches high at the wide end, 18 inches long and narrowing at the other end to 4 inches wide, and 4½ inches in height. *Fig.* 6. is a plan of the under surface of the tuyere iron. *Fig.* 5. represents the size and dimensions of the tuyere plate, which when bedded receives upon its surface the tuyere iron, *fig.* 7. This plate is first laid upon a bed of fire clay, with its narrow end towards the hearth, and inclined to rise a little. The tuyere is then introduced upon its surface, height and distance being attended to in the disposition of the plate, and the space betwixt its surface, and the sand-stone of the furnace, rammed very perfectly with balls of good fire-clay mixed with small fragments of fire bricks. When about to blow, the nose or inner end of the tuyere is covered with a very plastic clay, to prevent it from heating and burning away. This is always carefully attended to, and the blast put off at any time to replace it. Should it be neglected at any time, the iron would inflame with such rapidity, that an opening would be instantly made, by which the cokes and ignited matter of the furnace would be recoiled with the greatest violence imaginable.

Fig. 2. *Plate* XIII. The dam-stone. This is actually the dam, or barrier, which prevents the fluid contents of the furnace from advancing, and making their escape into the sand of the casting house. It is generally made from the same stone as the hearth, but is found still more difficult to stand for any length of time the action of the fluid iron, than the hearth to resist the ravages of the blast.

Fig. 3. dam plate. This is laid against the dam stone with a bed of fire clay interposing, and closes the front of the furnace. Its form is double, so that by turning it serves the purpose twice. It often fails, owing to the constant current of lava passing over the curvature *a*, and deepening it, till the iron flows over along with the cinder.

Fig. 4. the tymp plate. This embraces the under end of the tymp stone, and the sides of the hearth for three feet up. The thickness at bottom, called the heel, or cod, is preserved from the action of the fire by a strong stopping of clay.

This is replaced at least every cast, and prevents the flame and heated materials of the furnace from being blown forward.

Plate IX. *fig*. 4. is a ground plan of the arch pillars, hearth, tuyeres, and vents of a blast furnace.

A, the hearth, or particular spot where the fluid metal is collected.

B, the dam-stone.

c, the fall, or opening, by which the metal is discharged. After the cast it is filled with sand, which soon hardens and presents a very close texture to the fluid metal within. At the following cast it is cut carefully down, till the bar penetrates to the quick. A circular incision is then made, and the metal flows out of the orifice in a connected round stream, into the runner or channel made in the sand.

d d d d, four vents or openings which communicate with the false bottoms. *Plate* I. *fig*. 2. These serve to convey the damp from the furnace bottom, and by being run out into the external air, two in the front of the hearth, and one at each tuyere, indicate by their temperature, and the quantity of steam or vapour which they emit, the real state of the bottom below.

D D, the two pillars which support the front arch; they, at the same time, serve as abutments to one leg of each of the tuyere arches. The arch at the front is 15 feet wide and 15 feet high, and inclines to the centre of the furnace, in the same manner as the side walls of the pillars approach.

E, main or back pillar built entirely solid.

FF, vent holes six inches square, carried up from the foundation, and brought forward to meet the open air every four or five feet.

G G G G G G, tops of the pillars covered with cast iron plates, for receiving three large cast iron lintels, 10 feet long, and 10 inches square. These serve to give solidity to the arch, and support the lining and boshes of the furnace. *Fig*. 8, 9, different forms of tuyere pipes.

Blast-*Furnace*.—*History of its Origin and Progress*.

In detailing the progressive history of the blast furnaces, it is necessary to premise, that in this country it has undergone a revolution, of which we meet with no similar instance in other countries.

The most natural and abundant fuel which presents itself to mankind in their progress toward civilization, is that furnished by the numerous and extensive forests, which generally occupy the surface of a wide and uncultivated country. These, in the history of all nations, have been early appointed to domestic uses, and to the comfort of individuals. As a country became more populous, and the spirit of civilization increased, other advantages resulted from the general use of wood as fuel. The amelioration of climate, and the clearing of large tracts of land, making it subservient to the purposes of agriculture, were not the smallest benefits thus derived. As the progress of knowledge began to devise and establish regular manufactories, to supply the wants of the thriving community, the same sources of combustion were opened to the manufacturer and the artizan. These, as they became successful, were only preludes to other establishments more extensive, more lucrative, and entailing wants more difficult to supply. Among others the smelting of metals was no doubt of early origin, and equally dependent upon the woodland counties, in the immediate neighbourhood of the ores. In this class we can trace no metallurgical operation so hostile to the existence of wood, as an extensive manufacture of iron. If this manufacture, owing to the great and unexampled prosperity of the country, in place of remaining stationary, or exhibiting symptoms of decline, arising from a want of consumption of the article, has increased in capital, in extent, and riches beyond all precedent, wood, the base of the manipulation itself, depending only upon a stock rapidly declining, the existence of which was frequently incompatible with the views and interest of the landed proprietor, must soon have been annihilated, and the art of making iron lost to the community.

In this singular situation was Great Britain placed from the reign of Charles II. to the middle of the last century. The increasing manufactures, commerce and general prosperity of the country called loud for an additional supply of articles fabricated from iron, while wood, the foundation of the whole art, was rapidly declining in point of quantity, without the most distant prospect of ever being again renewed. Pit coal had been long before the latter period suggested as a substitute, but prejudice, interested views of established capitalists, and above all, a want of command of mechanical power, had prevented any successful operation from being established in this new department of iron making. No sooner, however, were these barriers to improvement broken through, and a change of fuel in the blast furnace found to be attended with profitable effects, than the languishing state of the trade began to revive, and improvements succeeded each other, with a facility new and astonishing. In fifty years the revolution was complete whether the consideration regards the increase of the manufacture, the general use of pit coal in the blast furnace, or the almost total annihilation of the charcoal mode of making iron.

It is uncertain at what period the manufacture of iron commenced in Britain. It is probable, that the working of the tin mines of Cornwall, by the Phœnicians, would introduce into the country a class of men skilled in all the then known metallic ores, capable of appreciating their true value, by converting the riches of an unexplored country, either to their own immediate necessities, or to the conveniences of the unskilful inhabitants. The invasion of England by the Danes, and their consequent establishment, would most likely add to the former stock of knowledge, in the art of mining and fusing iron ores. Whatever truth there may be in this conjecture, the fact stands unquestioned, that in several counties in England large heaps of scoria are found with an accumulation of soil sufficient to bear large trees. These have been from time immemorial called "Danes cinders." So early as 1620, Dudley remarks, that large oaks were then found in a state of decay upon the tops of some of these hills of scoria. It is not, however, probable, that these cinders were the product of the blast furnace. At a period so remote as that, wherein these heaps of scoria must have been accumulated, the labours of the iron maker were chiefly directed to the fabrication of small portions of malleable iron in *foot blasts* and *bloomeries*. The art of moulding and casting in iron was either totally unknown, or so very rude, as to excite no interest in favour of prosecuting this fine branch of art. If pig or cast iron was at all formed, it was merely of the most infusile nature, for being speedily converted into malleable iron. It was not till long afterwards, when improvements had taken place in the rude machinery of the times, and a division of labour seemed to be productive of many advantages, that different furnaces existed: one for the making of pig iron, and another for the conversion of it into malleable iron. This first gave rise to the blast furnace, which, properly speaking, was an improvement resulting from the knowledge of the advantages derived from a division of labour. After the appropriation of the blast furnace to the exclusive manufacture of pig iron, the manufacturer would soon discover, that the products of

his furnace were frequently different from each other. Experience and obſervation would ſoon enable him to decide, from whence this had its origin. A ſmall additional quantity of fuel, beyond that he formerly uſed for forge-pig-iron, he found, would confer a degree of fuſibility upon the metal that immediately pointed out the practicability of caſting it into ſhape. Moulding from thence would moſt likely enſue, and become equally an appendage to the blaſt furnace as was the bar-iron forge. As this new manufacture became familiar to the proprietor, he would immediately find his intereſt in dividing the product of his blaſt furnace into grey melting iron or into forge pigs, as the exigencies of his moulding ſhop, or forge required.

If credit could be given to the "Metallum Martis" of Dudley, in the 12th year of James, anno 1615, there were at that period not leſs than 300 blaſt furnaces for ſmelting iron-ore with charcoal, each of which had fuel, upon an average, for 40 weeks per annum. The average produce in pig-iron at each furnace of 15 tons per week, or 600 tons per annum, makes the total yearly quantity 180,000 tons, being a greater quantity than has ever ſince been manufactured in Britain.

However much this quantity may be exaggerated, yet it is highly probable, that even at this early period, the iron buſineſs in general, and the particular operations of the blaſt furnace, had obtained an eminent rank in the manufactures of the country. The progreſs of agriculture, and the increaſe of population under the reign of the peaceable James, had taught the huſbandman and the proprietor the value of cultivated fields. The great conſumption of wood for the navy and iron-works had greatly exhauſted the principal foreſts of ſupply; tracks of country became cleared, and as the ſpirit of cultivation increaſed, the annual quantity of fuel for the manufacturing of iron diminiſhed.

It is probable that Mr. Dudley, in eſtimating the quantities produced from each furnace, formed his average from the winter and ſpring months, when water was plentiful, and he ſeems not to have made ſufficient allowance for the occaſional ſtoppages in ſummer, during the time of cutting and collecting the wood for the enſuing wet ſeaſon. If, therefore, in place of making 600 tons yearly, the furnaces of theſe days are ſuppoſed to have made each, upon an average, five tons per week, or making a little allowance, 250 tons yearly, which is ſurely nearer the truth, this ſtill leaves an annual amount of manufactured pig-iron equal to 75,000 tons, which, excluſive of the operations of the forge, forms a very reſpectable ſtaple at that early period of the hiſtory of our manufactures.

Pit coal had been long known before this period, and wrought at Newcaſtle prior to the year 1272. Annually vaſt quantities of it were exported to Holland and the Low Countries, for the uſe of the ſmithy, and other manufactures requiring an intenſe and continued heat. Yet in England prejudices ran ſo ſtrong againſt its application to the manufacture of caſt-iron, that the projectors of this original undertaking met with every obſtacle which the narrow unenlightened minds of the eſtabliſhed manufacturers could deviſe.

James granted ſeveral patents for the excluſive right of manufacturing iron with pit coal. None of the projectors, however, were ſucceſsful, till the year 1619, when Dudley ſucceeded in making coak pig-iron in a blaſt furnace, though only at the ſparing rate of *three tons per week*. At this period many of the iron works were at a ſtand for want of wood, and the conſequence was an advance upon the price of iron: this rendered it a lucrative buſineſs to thoſe manufacturers whoſe ſupply of wood was ſtill undiminiſhed, and of courſe made them hoſtile to any innovation, whereby the preſent price of iron was likely to meet with a reduction.

This period of prejudice, ſo unfavourable to innovation in the iron buſineſs, was followed by one more general and more calamitous for the nation: amidſt the diſtraction occaſioned by civil war, neither innovation nor improvement could be expected. Patents, however, were granted to ſome during the common-wealth, for the excluſive manufacture in the new way, in one of which, it was at the time believed, that Cromwell was a partner: theſe partly ſhared the ſame fate with the firſt inventor, and none ſucceeded in eſtabliſhing a manufactory either of extent or certainty. In 1663, we find Dudley applying for his laſt patent, and ſetting forth, that at one time he was capable of producing ſeven tons of coak pig iron weekly, with an improved furnace 27 feet ſquare, and bellows, which one man could work for an hour without being much tired.

It was not, till impelled by neceſſity, ariſing from the rapid decline of the annual growth of timber, that pit coal became an object of univerſal eſtimation. When improvements on machinery had attained a pitch of certainty, and experience had taught the mechanic the manifold advantages of the ſteam engine; the adventurous manufacturer found he poſſeſſed an extent of means to which he was formerly a ſtranger. Small furnaces, ſupplied with air from leathern bellows, blown by oxen, horſe, or human labour, became exploded, and an increaſe of ſize took place, together with an increaſe of the column of blaſt neceſſary to excite combuſtion.

At this eventful era in the hiſtory of the blaſt furnace, when the ameliorating hand of agriculture was progreſſively ſweeping before it, what remained of the once immenſe tracts of woodland dedicated to the ſupply of the blaſt furnace; when the general improvement in machinery, and the introduction of the ſteam engine threatened to give new life and impulſe to manufactures in general, the iron-buſineſs ſeemed dwindling into inſignificancy and contempt. The demand of the country increaſed for the manufactured article, particularly bar-iron, while every year ſaw a gradual but ſteady diminution of the annual quantity. Recourſe to foreign markets was had for a ſupply of that article, of which this country once was the greateſt exporter, and the immenſe annual importations from Ruſſia and Sweden may date their origin from that period. The flouriſhing and extenſive detail of Dudley no longer exiſted, and the 300 blaſt furnaces of his day were now diminiſhed to 59 in all; the total amount of whoſe annual produce was 17350 tons, or nearly 300 tons to each furnace.

LIST of the Blaſt Furnaces in England and Wales immediately before the introduction of pit coal, as a ſubſtitute for the charcoal of wood; the particular counties in which they were ſituated; the collective quantity of iron manufactured in each county, and the produce of each particular blaſt furnace.

Counties.	Furnaces in each county.	Names of the Furnaces.	Total num of furnaces.	Iron made at each furnace.	Iron made in each county.
Brecon	1	Ynyſkedwyn	1	200	
	1	Lamthy	1	400	
	2	furnaces.			600
Glamorgan	1	Neath	1	200	
	1	Berſilly	1	200	
	2	furnaces.			400
		Carried forward	4		1000

Counties.	Furnaces in each county.	Names of the Furnaces.	Total num. of furnaces.	Iron made at each furnace.	Iron made in each county.
		Brought forward	4		1000
Carmarthen	1	Kidwelly - -	1		100
Cheshire	1	Valercydle - -	1	600	
	1	Lawtone - -	1	600	
	1	Dodington - -	1	500	
	3	furnaces.			1700
Denbigh	1	Waddoch - -	1	300	
	1	Ruabone - -	1	250	
	2	furnaces.			550
Derby	1	Staveley - -	1	150	
	1	Foxbrooke - -	1	150	
	1	Wingworth - -	1	200	
	1	Wanely - -	1	300	
	4	furnaces.			800
Gloucester	1	Blabney - -	1	600	
	1	Elmbridge - -	1	500	
	1	Flaxley - -	1	700	
	1	Redbrooke - -	1	600	
	1	Ditto - - -	1	200	
	1	Sidney - -	1	250	
	6	furnaces.			2850
Hereford	1	St. Waynarde -	1	300	
	1	Bingwood - -	1	450	
	1	Bishopwood - -	1	600	
	3	furnaces.			1350
Hampshire	1	New Forest Firne -	1		200
Kent	1	Lamard - -	1	100	
	1	Barcline - -	1	100	
	1	Horsden - -	1	100	
	1	Handberst - -	1	100	
	4	furnaces.			400
Monmouth	1	Pontypool - -	1	400	
	1	Ditto - - -	1	500	
	2	furnaces.			900
Nottingham	1	Kirkby - - -	1		200
Salop	1	Salop - - -	1	400	
	1	Bowlden - -	1	400	
	1	Willy - - -	1	450	
	1	Ditto - - -	1	200	
	1	Leighton - -	1	400	
	1	Kimbrotten - -	1	250	
	6	furnaces.			2100
		Carried forward	37		12150

Counties.	Furnaces in each county.	Names of the Furnaces.	Total num. of furnaces.	Iron made at each furnace.	Iron made in each county.
		Brought forward	37		12150
Stafford	1	Bradley - -	1	400	
	1	Wincheath - -	1	600	
	2	furnaces.			1000
Worcester	1	Bewdly - -	1	200	
	1	Hated - - -	1	500	
	2	furnaces.			700
Sussex	1	Ashburnam - -	1	500	
	1	Bubley - - -	1	100	
	1	Bread - - -	1	100	
	1	Robert's bridge -	1	100	
	1	Bery - - -	1	100	
	1	Darwille - -	1	100	
	1	Heathfields - -	1	100	
	1	Crunsuple - -	1	100	
	1	Lord Pelham -	1	100	
	1	Ditto - - -	1	100	
	10	furnaces.			1400
Warwick	1	Alton - -	1	400	
	1	Pooliband - -	1	300	
	2	furnaces.			700
York	1	Band, upper, -	1	200	
	1	Band, lower, -	1	200	
	1	Barnby, - -	1	300	
	1	Rosbley, upper, -	1	200	
	1	Ditto, lower, -	1	200	
	1	Chappel - -	1	300	
	6	furnaces.			1400
		Furnaces	59		17350

	Tons.	cwt.	qr.
Annual average for each furnace	294	1	1

By this statement it is evident, that the manufacture of pig-iron had diminished during one hundred to one hundred and thirty years preceding, upwards of 50,000 tons annually. Fortunately for the existence of the trade, the application of good going, and what, at that time, would be reckoned powerful, steam engines, about the year 1750, for raising and compressing air, were introduced at some places where abundance of materials was found without water for turning machinery. The manufacturer now found that his produce could be increased by enlarging the diameter of his steam cylinder, or perfecting the vacuum under the piston; and it was soon discovered, that these increased effects alone were requisite to the formation of pig-iron, in profitable quantity from the coke of pit-coal; nor is it to be wondered that this secret remained so long a mystery. The small quantity of air that was formerly requisite to ignite a charcoal furnace, whether from the great inflammability of the fuel, or the smallness of its capacity, was constantly before the eyes of the manufacturer. He had more often felt the effects of over-blowing, than under-blowing his furnace; and it is highly probable, that pit-coal, being deemed every way

inferior, an unuſual timidity would precede any movement that might have for its object the enlargement of the column of air or the increaſe of its denſity.

This, however, once done away, there ſeemed no end to the quantity of air that a coke blaſt furnace could with propriety receive before any bad conſequences enſued. Denſity, however, was found inimical to quantity, and the ſame law was at laſt diſcovered to hold good regarding pit coal as with wood, that the ſofter qualities could be over blown, while the more denſe and compact ſtrata remained undiminiſhed before a heavier blaſt.

The celebrated foundery of Carron was begun about the year 1760, and as was the cuſtom of the times, the operation of blowing was performed by large bellows moved by means of a water wheel. Pit coal was the ſtaple fuel in view, but the ſcanty ſupply of air, and its want of denſity, ſeldom permitted the produce of the furnace to exceed 10 or 12 tons weekly, and frequently, in ſummer, the quantity was reduced even below this. The company collected immenſe quantities of charcoal wood, and found their blaſt much better calculated for the operation of ſmelting with it, than the uninflammable pit coal obtained in their neighbourhood. Experience, however, gradually unfolded means of adopting machinery, more calculated to the nature of the coal fuel, more powerful wheels were conſtructed, the bellows was abandoned, and in their place large iron cylinders were introduced blowing both up and down. A larger column of air of triple or quadruple denſity was obtained, and effects equivalent to theſe great improvements followed at the blaſt furnaces. The ſame furnaces that formerly yielded 10 and 12 tons weekly, now ſometimes produced 40 tons in the ſame ſpace, and on the average in one year not leſs than 1500 tons of metal.

From the period (1750 to 1760) that pit coal coke was applied as a ſubſtitute for wood charcoal in the blaſt furnace, the iron trade began immediately to revive, and its progreſs in England and Wales, in a period of 30 years, was truly aſtoniſhing. The general uſe of pit coal, moſt unqueſtionably, occaſioned an earlier relinquiſhment of many of the charcoal works, than would have otherwiſe been the caſe, but the collective manufacture had ſo much increaſed, as to render this an object of trifling importance.

The following is a correct ſtatement of the annual manufacture of pig-iron in England and Wales in the year 1788:

Charcoal Blaſt Furnaces.	No. of Furnaces.	Tons at each.	Total in each County.
Glouceſterſhire -	4	650	2600
Monmouthſhire -	3	700	2100
Glamorganſhire -	3	600	1800
Carmarthenſhire -	1	400	400
Merioneth - -	1	400	400
Shropſhire - -	3	600	1800
Derbyſhire - -	1	300	300
Yorkſhire - -	1	600	600
Weſtmoreland -	1	400	400
Cumberland -	1	300	300
Lancaſhire -	3	700	2100
Suſſex -	2	150	300
Total of charcoal furnaces	24		13100

	Tons.	cwt.	qr.
Average produce from each furnace -	545	16	2
Former average produce - -	294	1	1
	251	15	1

Increaſed produce per furnace, from the year 1750 to 1788, attributable entirely to the general improvement of machinery, and the introduction of the ſteam engine, 251 tons, 15 cwt. 1 qr.

	Tons.
About the year 1750 the annual quantity of charcoal pig-iron manufactured in England and Wales amounted to - -	17350
In 1788 the ſame was - - -	13100
Decreaſe in charcoal iron betwixt 1750 and 1788	4250

attributable chiefly to the decreaſe of wood, but alſo in part owing to the uſe of pit coal as a ſubſtitute in the furnace.

Coke Pig Blaſt Furnaces in 1788.	No. of Furnaces.	Tons at each.	Total in each County.
Shropſhire -	21	1100	23100
Staffordſhire -	6	750	4500
Derbyſhire -	7	600	4200
Yorkſhire -	6	750	4500
Cumberland -	1	700	700
Cheſhire -	1	600	600
Glamorganſhire -	6	1100	6600
Brecknockſhire -	2	800	1600
Staffordſhire 3 new furnaces expected to blow ſame year	3	800	2400
Total furnaces and coke pig-iron manufactured in 1788 -	53		48200

An article entirely new, which though not diſcovered, was rendered a profitable and highly uſeful manufacture in the laſt 30 years.

Average produce at each furnace 907 tons.

	Tons.
Total of charcoal iron -	13100
Ditto of coke pig-iron -	48200
Total of pig-iron manufactured in England and Wales annually - - -	61300

At the ſame period in Scotland there were erected, and in blaſt, charcoal furnaces in the weſt Highlands, viz.

	No of Furnaces.	Tons each.	Total.
Goatfield - - -	1	700	700
Bunawe - - -	1	700	700
Coke pig furnaces, viz.			
Carron - - -	4	1000	4000
Wilſontown, or Cleugh - -	2	800	1600
Total quantity of pig-iron manufactured in Scotland - -	8		7000

Average produce for each furnace annually 875 tons.

Total quantity of pig-iron made in England and Wales	77	61300
	85	68300
Annual quantity manufactured immediately preceding the introduction of pit coal for furnace fuel -	59	17350
Annual increaſe in 30 years	26	50950

The period of 1788 or 1790 may be called a new æra in the manufacturing of pig-iron. The double power engine of Mr. Watt had now become more general, and was

yearly finding its way into blaſt furnace works. The regular and increaſed effects of this very powerful machine were ſoon felt in moſt of the iron counties. The produce of the furnaces in metal greatly increaſed as to quantity, and as they became more proſperous, ſtimulated others to engage in ſimilar undertakings. New works were yearly projected, and ſeveral blowing furnaces annually added to the former liſt: ſo that in eight years the manufacture of pig-iron had nearly doubled itſelf.

The following table is a curious illuſtration of this fact. It was drawn up as an authentic document of the returns made from all the blaſt furnace proprietors in Britain, of the number of their furnaces, and the annual quantity of pig-iron manufactured at their reſpective founderies. Theſe returns were made at a time when it was in the contemplation of the legiſlature to impoſe a tax upon pig-iron, and are copied from Dr. M'Nab's letter to the chairman of the committee of the houſe of commons upon the ſubject of the coal trade.

NAMES of all the FURNACES in Great Britain, with the Exciſe Return of the Quantity of Pig Iron made in 1796; the Quantities ſuppoſed and calculated upon; and the Returns of the Quantities really made.

NAMES OF FURNACES.	No. of Furnaces.	Diviſion.	Exciſe Return.	Suppoſed Quantity.	Exact Return.	From whom this Information was received.
Apedale, - -	1	Cheſter	2100	1000	728½	T. S.
Silverdale, - -	1	Do.	2600	1200	1230	Ditto.
Bear poſt, - -	1	Cumberland	2080	1200	240	W. R.
Dudden, - -	1	Do.	1664	400	325	E. K.
Newland, - -	1	Do.	700	700	700	Exciſe.
Backbarrow, - -	1	Do.	700	700	769	E. K.
Dale Abbey, - -	1	Derby	474	474	443	A. R.
Morſey Park, - -	1	Do.	728	728	728	Exciſe.
Butterſby, - -	1	Do.	936	936	936	Do.
Flaxley, - - -	1	Glouceſter	360	360	360	Do.
Foreſt of Dean, - -	1	Do.	20	20	20	Do.
Abbey Tintern, - -	1	Hereford	70	70	70	ot exactly known
Biſhopwood, - -	1	Do.	500	500	947	E. K.
Cornbrook, - -	1	Do.	1000	1000	482	W. R.
Bringwood, - -	1	Do.	500	500	250	Do.
Leighton, - -	1	Do.	780	780	780	Exciſe.
Bowling, - -	2	Leeds	2000	2000	2000	J. H.
Wibſey Moor, - -	2	Do.	2000	2000	2500	Do.
Shelf, - - -	1	Do.	1000	1000	1140	Do.
Birkenſhaw, - -	1	Do.	780	780	846	Do.
Reniſhaw, - -	2	Lincoln	500	500	705	J. W.
Old Park, - -	3	Salop	11332½	6240	5952	W. R.
Horſehay, - -	1	Do.	4927½	2080	1458$\frac{4}{20}$	Do.
Lightmoor, - -	3	Do.	8946	6240	3498$\frac{15}{20}$	Do.
Coalbrook Dale, - -	3	Do.	7175	4162	2659$\frac{11}{20}$	Do.
Madely Wood, - -	1	Do.	3777½	2080	1856$\frac{8}{20}$	Do.
Jackfield, - -	2	Do.	7086	4160	1820	Do.
Benthal, - -	1	Do.	2367½	1600	1334	Do.
Willey, - -	1	Do.	3702½	1600	1554½	Do.
Broſely, - -	1	Do.	1775	1400	1076½	Do.
Ketley, - -	3	Do.	7590	6240	5068$\frac{18}{20}$	Do.
Snedſhill, - -	2	Do.	4730	3400	3367½	Do.
Donnington Wood, -	2	Do.	4720	4160	3323	Do.
Cheſterfield, - -	1	Sheffield	940	940	940	Exciſe.
Little Brampton, -	2	Do.	1800	1800	1560	Meſſrs. S.
Winger Worth, - -	1	Do.	1274	1274	1274	Exciſe.
Stavely, - -	1	Do.	1000	1000	761	W. W.
Park, - -	1	Do.	1092	1092	853	J. W.
Chapel, - -	1	Do.	1456	1456	1456	Exciſe.
Horncliffe, - -	2	Do.	1092	1092	712	J. W.
Elſhar, - - -	1	Do.	800	800	950	Do.
Brelton, - -	1	Do.	250	250	250	Exciſe.
Holmes, - - -	3	Do.	6000	6000	2000	J. W.
Aſhburnham, - -	1	Suſſex	172¾	173	173	Exciſe.
Clydach, - -	1	South Wales	1820	1820	1625	E. K.
Carried forward -	63		107,318¼	77,905	61,722$\frac{17}{20}$	

NAMES OF FURNACES.	No. of Furnaces.	Divifion.	Excife Return.	Suppofed Quantity.	Exact Return.	From whom this information was received.
Brought forward,	63		107,318¾	77,905	61,722 11/20	
Blandare,	1	South Wales	1404	1404	1500	E. K.
Blanavon,	3	Do.	5460	5460	4318	Do.
Sirhowy,	1	Do.	1820	1820	1930	Do.
Beaufort,	1	Do.	1560	1560	1660	Do.
Penyca, or Ebbervale,	1	Do.	1560	1560	397	Do.
Hirwain,	1	Do.	1400	1400	1050	Do.
Melynicourt,	1	Do.	648	648	503	Do.
Ennifygedyr,	1	Do.	1352	1352	800	Do.
Caerfilly,	1	Do.	600	600	695	Do.
Cyfartha,	3	Do.	6000	6000	7204	R. C.
Plymouth,	1	Do.	2000	2000	2200	E. K.
Pendarron,	2	Do.	4000	4000	4100	Do.
Dowlais,	3	Do.	4100	5400	2800	Do.
Llanelly,	1	Do.	1664	1664	1560	A. R.
Dovey,	1	Mid Wales	200	200	150	E. K.
Ruabone,	1	North Wales	1560	1560	1144	W. R.
Brymbo,	1	Do.	884	Silent		Do.
Brymbo-gate,	0	Do.	728	None		Do.
Penyvron,	0	Do.	1498	Lead work		Do.
Pentrobn,	0	Do.	1560	Do.		Do.
Carmarthen,	1	W. Wales	1056	1056	290	E. K.
Level,	1	Staffordfhire	1560	1560	1391	T. S.
Brierly,	1	Do.	1300	1300	1046½	Do.
Deepfield,	2	Do.	2600	2600	2526	Do.
Bilfton,	2	Do.	2340	2340	1429	Do.
Bradley,	3	Do.	3640	3000	1920	Do.
Grave yard,	1	Do.	1260	1336	213	Do.
Dudley port,	1	Do.	1040	1040	869	Do.
Tipton,	2	Do.	2080	2080	2203	Do.
Gofpel Oak,	1	Do.			1613	Do.
Neath Abbey,	2	South Wales	3120	3120	1759	E. K.
	104		167,312¾	133,965	108,993 7/20	

SCOTCH FURNACES.

NAMES OF FURNACES.	No. of Furnaces.	Excife Return.	Suppofed Quantity.	Exact Return.	From whom this information was received.
Carron,	4	5200	5200	5616	T. E.
Wilfontown,	2		2080	2080	A. H.
Muirkirk,	2		3120	2878	T. E.
Clyde,	3		3640	2216	Do.
Omoa,	2		3000	2396	Do.
Devon,	2				
Goatfield, (Charcoal)	1		1600	300	E. K.
Bunawe, Do.	1			600	T. E.
	17		18,640	16,086	
Manufactured in England and Wales,	104		133,965	108,993	
Grand Total,	121		152,605	125,079	

Average Produce of each of the Englifh and Welfh furnaces, 1048 Tons per Annum.
Ditto of each of the Scotch Furnaces, 946

The demand for iron articles of all kinds in this country not only continued unabated after the period of 1796, but kept increasing in a greater ratio than formerly; so that in the short space of five years, situations were occupied for nearly 50 additional furnaces, or additions made to established works of that extent. Betwixt 1801 and 1802, it was ascertained that the following new furnaces were either building or actually in blast, in England, Wales and Scotland.

In England and Wales.

	Blowing.	Building.
Silverdale,	1	0
Snedshill,	2	0
Wibsey Moor,	1	0
Ketley,	1	0
Madely Wood	1	0
Burnet's Leasow,	1	0
Newcastle, Staffordshire	0	1
Cyfartha, South Wales,	1	0
Llanelly, Do.	1	0
Sirhowy, Do.	1	0
Beaufort, Do.	1	0
Plymouth,	1	0
Union,	0	1
Aberdare,	0	3
Tipton, near Billston,	1	1
Bloomfield,	0	1
Longacres,	0	1
Wednesbury,	0	1
Staffordshire,	1	0
Coleford, Gloucestershire	1	0
Jackfield,	1	0
Old Park,	0	1
Donnington Wood,	0	1
Deepfield, Staffordshire,	1	0
Gornall Wood, Do.	1	0
Brierly Hill,	1	0
Billston,	1	0
———, near Wolverhampton,	0	1
Dudley Wood,	0	5
Billingsly, Shropshire,	0	1
Newcastle upon Tyne,	0	2
	20	20

In Scotland.

	Blowing.	Building.
Muirkirk,	1	0
Glenbuck,	1	0
Calder,	0	2
Markinch,	0	2
Shotts,	0	1
	2	5
Total of new Blast Furnaces	22	25

Blowing and building in Great Britain; the produce of which, supposing them all to have gone to work at the rate of 1000 tons per annum, from each furnace, would amount to, from 47 furnaces, 47,000 tons,

Manufactured at, and previous to 1796, in } 121 furnaces, 125,079

168 furnaces, 172,079 tons

The respective proportions of this astonishing produce in pig iron manufactured in England and Wales, and in Scotland, will stand thus:

	Furnaces.		Tons.	
England and Wales, in 1796,	104		108,933	
Ditto, since that period,	40		40,000	
		144		148,993
Scotland, in 1796	17		16,086	
Ditto, since that period			7,000	
		24		23,086
Grand total in Britain,		168	making	172,079

In recapitulating the interesting facts which will result from a review of the gigantic progress of this manufactory, the regular progressive quantity made at a furnace is remarkable, or, which is the same, a diminution of the number of furnaces to perform the same quantity of labour.

Dudley represents, that in his day, 1620, there existed, in England and Wales alone, 300 blast furnaces, for the sole making of pig-iron, to each of these have been assigned the yearly produce of - - - 250 tons.

At a period considerably after this, and before the use of pit-coal was found profitable in the furnace, 59 furnaces produced yearly 17,350 tons of charcoal iron, or each furnace average, 294

In 1788, there still existed in England 24 charcoal furnaces, which yearly manufactured 13,100 tons of metal, or from each furnace, on an average, - - - 545

At the same period, in England and Wales, 53 blast furnaces, at which coke was used, manufactured yearly 48,100 tons, which upon an average was nearly, from each furnace, - 907

The same year in Scotland, 8 furnaces produced 7000 tons of iron, or from each furnace, 875

In 1796, the number of furnaces in England and Wales amounted to 104, and yielded 108,993 tons of metal, which from each furnace was equal to - - 1048

The same year, in Scotland, 17 furnaces manufactured 16,086 tons of pig-iron, which is from each furnace, - - 946

These are by no means sufficient data to form an accurate opinion of the real progress or improvement of our blowing machinery in Britain. In the collection of furnaces in 1796, a number of charcoal blasts were included, which, from their general small produce, blowing only four, six, or nine months a year, reduces the average considerably on the whole. It may now be safely asserted, that the average produce in iron at pit-coal blast furnaces in England and Wales, is at melting iron works, - 1200 tons

Do. at forge pig works, 2000

This bears a very striking contrast to the early exertions of the manufacturers in the sixteenth and seventeenth centuries, and exhibits a wonderful example of the general and rapid improvement of machinery in the last 50 years. With the improvements of machinery, the advancement of the manufacture of iron in general, and particularly of coke pig-iron, has kept equal pace. Nor have we sacrificed quality to quantity, but the reverse; for the melting pig-iron of our time is much more calculated for every variety of casting, than iron, equally saturated with the coaly principle, made with wood charcoal.

By comparing the value of a ton of pig-iron at different periods for the last 200 years, a pretty accurate opinion may be formed of the increased price of labour at iron works, and of the increased value of an object of universal utility in all our arts and manufactures.

About the year 1620, charcoal pig iron fold for	6l. per ton.	
1788, ditto for melting, -	8l.	
1798, ditto - -	9l.	10 s.
Coke pig iron, when firft invented by Dudley, was fold at - - - -	4l.	
In 1788, it fold for -	5l.	10 s.
1798, ditto - -	7l.	10 s.
1802, melting iron was -	8l.	10 s.
And fmooth-faced N° 1. fold at - -	9l.	10 s.

One thing is here worthy of remark, that in a period of 170 years one ton of coke pig iron rofe in value only 30 s. i. e. betwixt 1620 and 1788; but that in the fhort period of 14 years following 1788, an advance of 4l. per ton took place. One thing only may be offered in extenuation of this immenfe rife, that part of it was owing to the mifunderftanding that took place betwixt this country and fome of the Baltic powers, which was no fooner adjufted than pig iron fell in price. The article ftill, however, maintains itfelf at 8l. 10 s. per ton, being double the rife in point of value in fourteen years that took place in the one hundred and feventy preceding the commencement of that period.

To point out proper channels, whereby to account for the annual confumption of fuch an immenfe quantity of raw materials, would prove a fatisfactory fource of information. The endlefs detail into which the foundery trade has now branched itfelf, the almoft univerfal fabrication which it embraces, and the extenfive diffufion of the fcites of manufactories themfelves, preclude the poffibility of obtaining this with ftrict accuracy. The following ftatement, however, will tend to throw fome light upon the fubject.

		Tons.
It is reckoned, that the bar iron forges in Britain manufactured annually from pig iron 40,000 tons of finifhed bars, which, at the rate of 35 cwt. of pigs for every ton of iron bar produced, will account for - - - - -		70,000
Confumed yearly in the erection of new furnaces, forges, machinery, &c. - - - -		5,000
Purchafed by the board of ordnance in the ftate of cannons, mortars, carronades, fhot, and fhells, &c. on an average of 1794, 5, 6, -	10,935	
Wafte in melting from the pig, boring, &c. - - - - -	1,300	
		12,235
Purchafed by the navy board in the ftate of ballaft, &c. - - - - - -		2,664
India Company's annual fupply in guns, fhot, fhells, carcafes, &c. -	5,000	
Wafte melting, boring, &c. -	700	
		5,700
Merchant guns, carronades, fhot, &c. for arming trading veffels, - -	10,000	
Wafte in melting and boring, -	1,000	
		11,000
Ballaft for Merchantmen and India men, -		5,000
	Tons	111,599

For the difference betwixt this and the total manufacture, recourfe muft be had to the large exportation to Ireland, and to the numerous and extenfive cafting founderies of London, Liverpool, Manchefter, Birmingham, Workington, Newcaftle, Edinburgh, Glafgow, &c. none of which melt under 2000 tons yearly, and many of them from 4 to 5000 tons of melting pig iron.

We fhall now leave this interefting fubject with fome general obfervations upon the origin and progrefs of the pig iron manufacture, and its early ufe in the fabrication of caftings.

It appears from Dudley, that towards the clofe of the reign of queen Elizabeth, blaft furnaces had been conftructed of fize, and with machinery fufficient to produce upwards of two tons of charcoal iron per day. Such great products in iron were moft probably confined to fituations where there was abundance of water, and where water-wheels and bellows of a confiderable magnitude were ufed. The more common modes of operation were confined to furnaces of an inferior fize, which were fupplied with air by means of hand-bellows, excited by cattle, or the labour of men. At the fame period England enjoyed a confiderable export trade, arifing from her fuperior manufacture of iron guns, mortars, &c. As pit-coal had not been applied in any branch to the manufacturing of iron, it is probable, that thefe articles would be caft from the large blaft furnaces; the flame of wood poffeffing but feeble effects compared to that of pit-coal, would render the application of the reverberating furnace, if then known, of no ufe in the cafting of guns and mortars.

The non-application of pit-coal in every department of the melting foundery, would greatly retard the perfection, or even improvement of the art of moulding, and cafting fmaller and more general articles. The want of it, as the fmelting fuel in the blaft furnace, was long feverely felt by the general backward ftate of the art of moulding and cafting in this country, and allowed other nations with fewer advantages to get the ftart of us. It is highly probable, that long before the period formerly alluded to, the application of pit-coal had been fpeculated upon, either as an auxiliary, or as a fubftitute in every branch of the iron bufinefs. Its well known inflammability and tendency to form a cinder, and the general decay of wood, would furnifh ample grounds for what, to many at the time, would be confidered as idle and vifionary fpeculations. The advantages arifing from the trade, as it was then fituated, had been rigidly afcertained, and fully appreciated by the eftablifhed manufacturers. The bufinefs, in point of extent, feemed only limited by the fupply of wood. New erections, for want of a proper fupply of materials, became impracticable; thofe already engaged were more anxious to preferve their fupply, however much circumfcribed, than liften to innovation, which, by fubftituting pit-coal for the charcoal of wood, would likely give to the fpeculatift a great fuperiority in the market. It is alfo highly probable, that many of the iron works then eftablifhed were at a confiderable diftance from pit-coal, the general introduction of which would prove fatal to their interefts.

In this view of the fubject, the adventurer with capital had every thing to hope, the eftablifhed manufacturer every thing to fear, by change. Under thefe circumftances, the difcovery, or rather the affertion of the practicability of making iron with pit-coal, was announced by Simon Sturtevant, efq. in the year 1612, who, upon application, was favoured with a patent from king James, for the exclufive manufacture of iron with pit-coal, in all its branches, for the long period of thirty-one years. In return, the faid Simon Sturtevant bound himfelf to publifh a faithful account of his difcoveries, which afterwards appeared in quarto, under the title of his "Metallica." It is uncertain to what caufes his failure was at the time attributed, but in the execution of his difcoveries upon a large fcale, he had found difficulties amounting to utter impracticability; for in the year following, he was obliged to make a furrender of his letters of monopoly.

The second adventurer in this unexplored path we find to have been John Ravenson, esq. who, like Sturtevant, was successful in obtaining a patent for the new manufacture; but, like him also, was inadequate to the completion of it upon a profitable scale. Ravenson was also enjoined to publish his discoveries under the title of his "Metallica," which was printed for Thomas Thorp, anno 1613. Several other adventurers stepped forth, all of whom had the mortification of resigning their patents, without having contributed to the success of their arduous undertaking.

In 1619, Dubley obtained his patent, and declared, that although he made only at the rate of three tons per week, he made it with profit.

This discovery was perfected at his father's works at Pensent, in Worcestershire. This gentleman's success in the various manufactures of iron with pit-coal, had united not only all the proprietors in the charcoal iron trade, but many new adventurers, who wished to share in the emoluments, or to acquire part of the fame of the new discovery. Their interest was sufficient to limit the duration of Dudley's patent from 31 to 14 years. During the greatest part of this period, according to his own statement, he continued to make pig and bar iron, and various castings; all of which he sold much lower than the charcoal manufacturers. In the article of castings he must have had greatly the start of the charcoal founderies, as the quality of melting coke pig-iron is far superior to that of charcoal, particularly that made in this country for the general purposes of casting. Nor was the superior genius of Dudley always an object of passive indifference in the narrow estimation of the new adventurers and the established manufacturers. The envy occasioned by his uncommon success, produced at last a spirit of combination, which terminated in a hostile attack upon his devoted works. His improved bellows, furnace, forge, &c. all fell a prey to a lawless banditti, betwixt whom and its furious leaders no shades of distinction were visible, but those of avarice, ignorance, and the most contemptible prejudice.

To evade the mode of operation discovered by Dudley, or to introduce the making of coke pig-iron with greater advantages, a new plan was adopted by captain Buck, major Wildman, and others, in the forest of Dean, where they erected large air-furnaces, into which they introduced clay pots resembling those used at glass houses, filled with the necessary preparations of ore and charcoal. The furnaces were heated with the flame of pit-coal; and it is probable, that by tapping the pots below, it was expected that the separated metal would flow out. This rude process of assaying on a large scale, was in the end found utterly impracticable; the heat was inadequate to perfect separation; the pots cracked; and, in a short time, the process was abandoned altogether.

The misfortunes which befel the sanguine, but unfortunate Dudley, were an irreparable loss to the perfection of the coke pig process. The hostile rivalships he had to encounter in consequence of the new ground he had occupied as a manufacturer, together with a zealous attachment to the royal cause during the civil war which followed his discovery, completely prevented his improvements from attaining a pitch of permanency and general utility. The refusal of a new patent after the restoration, prevented him from again entering the laborious paths of discovery and improvement, although it appears, that his former application to the perfecting of this branch of manufacture had not been unsuccessful, for in place of three tons of coke pig weekly, in his petition praying for a renewal of his ancient rights, he states, that he could now manufacture seven tons by means of a large furnace, and an improved bellows.

No greater pitch of improvement took place for nearly one hundred years after this period. The practicability of the manufacture was discovered; but the mode of obtaining quantity, to ensure in general a profitable return, depended upon other circumstances than the proportioning of the raw materials together. Had machinery received the same improvements in the time of Dudley, it is more than probable that the rapid progress of the coke pig trade would have dated its origin from that period. But this great era in the history of our manufactures was reserved for a much later date; and in the improvements of the steam engine, we see new life and existence conferred upon every species of art that can be made subject to motion or mechanical control.

Blast *Furnace Works*, are large and expensive buildings for the manufacturing of pig iron. An erection upon the smallest scale must consist of a furnace, casting-house, bridge-house, and blowing engine. The latter is sometimes, though seldom, worked by means of a water wheel. The most universal mode of blowing is by means of a steam engine. See Blowing *Machine*.

There is no general plan laid down for building a blast furnace work. The singular situation which should be occupied, to insure every conveniency, renders this dependent upon the nature of the ground.

It is always reckoned a great advantage to place the blowing machine at as short a distance as possible from the furnace or furnaces, that the air may have the least possible travel in the conducting pipes. When this cannot be conveniently effected, the diameter of the pipes ought to be made sufficiently large to admit of the blast passing without any material friction.

The usual appendages to blast furnaces are mines of coal, iron-stone, and lime-stone. And these form no inconsiderable portion of the whole expence.

In situations where blast furnace building materials are at a moderate price, and when no uncommon difficulty occurs in the progress of the general operations, 15000l. of sunk capital may be deemed requisite for one furnace; and for every furnace after this, 10,000l. may be added.

This great capital for many years kept the trade in the hands of a few; but of late, since capitalists have become more common, the number and extent of the blast furnace erections have become truly astonishing.

The following descriptions of plates illustrative of the plan and arrangement of blast furnace works will convey a tolerable idea of the nature of these buildings.

Plate XI. *Blast Furnace Works*, represents the ground plan of an entire fabric, consisting of

A steam-engine for blowing two furnaces.
2 Blast furnaces.
2 Bridge-houses.
1 Casting house.
1 Boiler-house.
2 Boilers.
1 Chimney for boiler flues.

A, Engine-house, 40 feet long, 18 feet wide.

B, Pedestal for steam cylinder: 7 feet square at base, and 4 feet at top.

C, Pedestal for blowing, or air cylinder. Base 10 feet square, top 7 feet square. These are generally built of solid hewn stone, and bedded with the greatest accuracy. From centre to centre of the two pedestals is 24 feet, which is also the distance betwixt centre and centre of the steam and air cylinders.

D, Door or opening through the lever wall. This wall at bottom is built $5\frac{1}{2}$ feet thick, but is occasionally reduced

in point of thickneſs to 3½ feet at top, as may be ſeen at the correſponding letter in the ſection.

F, Door or opening from the engine into the boiler-houſe. An opening above this ſerves to conduct the ſteam pipe from the boiler to the ſteam apparatus at the cylinder.

E, Door or opening for carrying through the blaſt pipes from the top and bottom of the air cylinder to the water receiver below.

G, The boiler-houſe, 40 feet by 30 within the walls. As this is excavated from the ſolid hill to the depth of 30 feet, it is requiſite to have the walls uncommonly ſtrong. Thoſe in the plan are 6 feet thick at bottom, and are reduced at three different heights in thickneſs, as repreſented by the interior lines.

H H, Two boiler ſeats for boilers, 18 feet long, 9½ feet high, and 7 feet wide.

I I, Fire-places, 6 feet ſquare.

K K, Dead-plates before the bars or grates.

L L, Openings where the furnace doors are hung.

M M, Semi-circular openings formed beyond the dotted line, or termination of the boiler, in which the flame from the grates riſes to enter the iron flue or tube, which is placed in the centre of the boiler.

N, Chimney, 2½ feet ſquare within, and 50 feet in total height; from the bottom of the flue 42, and 8 feet from the foundation.

O O, Coal pits for containing ſmall coals for the engine's ſupply. Theſe are 8 feet by 6 at bottom, and widen gradually as they approach the ſurface of the coke yard. The coals are there emptied from the cart into theſe receivers, and the engine-man eaſily ſupplies his wants from the ſmall openings which communicate with O into the boiler-houſe.

P P, Bridge-houſes for containing cokes, iron-ſtone, and lime-ſtone, for filling the furnace. Meaſurement within 42 by 40 feet.

Q Q, Doors or entrances from the coke yard into the bridge-houſes.

R R, Openings from the bridge-houſe, which is here connected with the furnace, by means of an arch and parapet walls. This is more fully ſeen in the elevation ſection P. Along this bridge the materials are carried or wheeled into the mouth of the furnace.

S S, Two blaſt furnaces, 34 feet ſquare in the baſe.

T, Caſting-houſe 102 feet long by 48 in width, from the front wall or arch of the furnace, or 88 feet wide from the front wall of the engine and bridge-houſes, and 24 feet high in the ſide walls.

W, Water receiver for receiving and equalizing the column of blaſt. Length 40 feet, and breadth 18 feet.

V, The ſpace in which the equivalent column of water riſes, 3 feet wide. The exterior line denotes the inverted iron cheſt; the interior lines, the different baſements formed by the ſtone work laid upon the cheſt to prevent it from riſing when the engine is at work.

Y, Termination of the blaſt conduct pipes from the air cylinder into the iron receiver, 2 feet 6 inches diameter.

Z, Poſition for the horizontal range of pipes to branch off, which are meant to convey the blaſt to the oppoſite tuyeres, *a a*, betwixt the back wall of the furnace, and the bridge-houſe.

b b, The two tuyere ſides next the water preſſure. From Y proceeds a ſtraight pipe along the centre line *b*, for conveying the blaſt to that ſide of the furnace.

c c, Front arches, under which the furnace workmen perform all the labour of tapping, caſting, and cleaning the furnace.

d d, The ſpaces incloſed within theſe dotted lines are called pig beds. They are kept conſtantly filled with ſand, and in them the operation of moulding and running the pig metal is conſtantly performed.

Plate XII. *Blaſt Furnace works.*

Elevated ſection of the ground plan, *Plate* XI. through N F B D C E and X.

A, Inſide of the blaſt engine-houſe.

B, Steam cylinder pedeſtal.

C, Blowing or air cylinder pedeſtal. Both of theſe are built upon 4 or 6 inch planking, laid upon ſtrong logs, which are again ſupported upon the ſolid ſtone buildings, *a a*, running from the lower wall along the ſide wall of the engine-houſe, to the wall perpendicular to E. The binding down bolts that paſs through the flanges of the cylinders are ſtrongly keyed upon the under ſide of the logs, and are at all times eaſily acceſſible.

D, The lever wall and opening of communication betwixt the ſteam and blowing end of the engine-houſe.

F, Door or opening into the caſting houſe and water regulators.

E, Door to the boiler houſe.

G, The boiler-houſe.

H, One of the boiler ſeats.

I, One of the boilers, 18 feet long, by 9½ wide, by 7 high.

K, Manhole door for entering the boiler.

L, Thorough arch in the foundation of the chimney.

M, Throat, or opening into the chimney, for the paſſage of the flame and ſmoke.

O, Coal pit for containing fuel for the engine.

P, Arched paſſage of communication betwixt the bridge-houſe and furnace mouth. The opening in the bridge-houſe is more diſtinctly ſeen at R, *Plate* XI.

S, Side view of one of the blaſt furnaces, as connected with its correſponding bridge-houſe.

W, Water vault, or ciſtern, for receiving the inverted cheſt. In rocky foundations this is cut out of the rock, but in ſoft ground the excavation is made and lined with well jointed maſon work, puddled behind with clay to prevent the loſs of water.

T, Caſting-houſe and roof.

b, The tuyere arch.

c, The ſow, or lintel of caſt-iron, 12 inches ſquare.

d, The orifice at which the blaſt enters, called the tuyere.

e, Spring beams of the engine houſe, A. Theſe are compoſed of two logs 14 inches ſquare. The main gudgeon, ſeat, and beam reſt upon theſe.

f, Stay logs for the ſteam cylinder.

g, Ditto, for the blowing cylinder.

Deſcription of *Plate* XIII. *Blaſt Furnace Works.*

Croſs ſection and elevation of *Plate* XI. through S Y S.

S S, Section of two blaſt furnaces, and their ſituation as connected with the blowing apparatus.

Y, The branch pipe for communicating the air to the inſide tuyeres of the furnace. This pipe has another branch of communication behind, which connects it to the blaſt pipes which deſcend from the blowing cylinder at A, and to the double column of pipes which are carried round behind the furnace to the oppoſite tuyeres.

C C, View of the pipes which convey the air to the oppoſite tuyeres, where double blaſts are in uſe.

D, Front wall of engine and bridge-houſes.

X, Iron cheſt inverted in the water receiver, and connected with the blaſt pipes.

V V, Opening all round for the water to aſcend, as it becomes expreſſed from the cheſt by the impelling force of the blaſt.

O, Logs on which the cheft is inverted, to preferve it from the floor of the water receiver, from 12 inches to 18 of fpace.

Defcription of *Plate* XIV. *Blaft Furnace Works.*

Ground plan of an extenfive blaft furnace foundery, confifting of four furnaces and two blaft engines. The peculiar conftruction of this plan is, that only one furnace may be erected at a time, and afterwards the whole number; ftill preferving that regularity and uniformity of defign which will at any time make the blowing machinery of one part fubfervient to the whole, in cafe of accidents, ftoppages for repairs, &c.

A, Engine-houfe, with cylinder, pedeftals, lever wall, openings, &c.

B B, Two boiler-feats and boilers.

CC, Water regulators for the blaft, which conveniently communicates, by means of pipes, with the blowing cylinders, placed upon the pedeftals behind A, I.

DD, &c. Centre line of the whole blaft pipes. This extenfive column may be fo arranged, as to enable the furnaces to be blown each with two tuyeres; and the blaft of one engine made to pafs through the whole. The general communication is effected by carrying the chief column either behind the furnaces, or, as in the plate, through the main pillar of the furnace, by means of an arched opening 3 feet wide.

E, Ground plan of the hearth, fquares, and pillars of four blaft furnaces.

FFFF, Bridge-houfes for materials, and filling or charging the furnace.

GGGGG, Openings into the furnace top.

H, Cafting-houfe.

I, Second blaft-engine, upon the fame plan as A. Each of thefe two engines ought to be calculated to blow two furnaces, and occafionally, when any thing goes wrong with one, the blaft of the other could be eafily diftributed for a time among all the furnaces.

BLASTED, in *Antiquity*, fomething ftruck with a *blaft*.

Among the Romans, places blafted with lightning were to be confecrated to Jupiter, under the name of *bidentalia*, and *putealia*. It was alfo a ceremonial of religion to burn blafted bodies in the fire.

BLASTING *of ftones*, in *Agriculture*, the operation of tearing afunder large ftones or rocks, which are in the way of the plough or other inftruments employed in breaking up ground, by means of gun-powder. The method of performing this bufinefs is by boring a large hole, eight, ten, twelve, or more inches deep, according to the nature and fize of the ftone or rock to be blafted, by means of a chifel for the purpofe, and then introducing a fufficient quantity of gunpowder, and afterwards carefully ramming the hole up with fmall fragments of ftone or other folid materials, only leaving a very fmall aperture, by placing a fteel pricker of fufficient length and fuitable dimenfions, with a handle at the top, at firft into the powder, and frequently turning it round while the hole is ramming up. After the hole is quite filled, by forcing the hard materials in with a proper inftrument, the pricker is withdrawn, and the aperture left by it filled to the top with gun-powder, and then a match of tow, ftraw, or other light inflammable material laid to it, and fet on fire.

It is obferved by Mr. Headrick, in the fecond volume of "Communications to the Board of Agriculture," that in order to perform this operation properly fome experience is neceffary, and that a fkilful workman can frequently rend ftones into three equal pieces, without caufing the fragments to fly about. This, he fays, depends upon the depth and pofition of the bore. It is alfo remarked, that a fmall portion of quick-lime, in fine powder, is found to increafe the force, and confequently to diminifh the expence of blafting ftones. On thefe grounds the following is offered as a fubftitute for gun-powder, which is now become very expenfive, though, as is freely confeffed, without any experience of its effects. Suppofing *fig.* 1, *Plate* III. (*Agriculture*) to be a large ftone to be blafted or rent; *ab*, a bore fent down into it in the ufual manner. This bore being then well cleaned out and dried, is to be filled from *b* to *c* with the pureft quicklime, or fuch as fwells moft in flaking. That it may be perfectly quick it fhould be taken red hot from the kiln, or the fmall furnace where it has been burnt; being then rammed in hard with the jumper or punch *a c*, the upper part of the bore is to be crammed with rotten rock in the ordinary way. The pricker being removed leaves the aperture at *b*, *a b*, a fmall pipe of copper, of lefs diameter than the needle or pricker, having an orifice about the dimenfions of the ftraw, ufed to convey the fire down to the gunpowder, with a funnel *d* to receive water, is introduced into the aperture. Perhaps a ftraw or fmall reed ftuck in the lower part of the funnel, among tallow or bees wax, might ferve the purpofe of a copper pipe. Things being thus prepared, pour water into the funnel *d*; and if the pipe be not too high, fo as to prevent the air from efcaping from the aperture, left by the pricker, it will defcend and caufe the lime to flake in the bore *c b*. Every one knows how irrefiftibly the pureft quick lime attracts water, and with what prodigious force it expands in flaking into three or four times its former bulk. From thefe data it is therefore inferred, that the flaking of lime, in fuch circumftances, would burft or rend the ftone *f* in pieces; but the fuccefs of fuch an experiment, it is obferved, muft depend entirely upon ufing lime of the utmoft purity, and having it very hot, and perfectly cauftic when it is put in.

It is further remarked that if the bore *c b* were filled with water, and the aperture afterwards rammed up, the water being made to freeze by cold, would rend the ftone; for when water paffes from a fluid to a folid form, it expands with irrefiftible force, though froft cannot be depended upon in this climate.

Bleaching

BLEACHING. The art of bleaching confifts in removing the coloured matters intermixed with vegetable and animal fubftances in their natural ftate, or fuch as they have fubfequently imbibed by accident, or fome artificial procefs. Edward Huffey Delaval, efq. F.R.S. has fhewn, by a number of accurate experiments on the caufe of the permanent colours of opake bodies, publifhed in the fecond volume of the fecond edition of the Memoirs of the Literary and Philofophical Society of Manchefter, "that when the colouring matter of plants is extracted from them, the folid fibrous parts, thus divefted of their covering, difplay that whitenefs which is their diftinguifhing character. White paper and linen are formed of fuch fibrous vegetable matter, which is bleached by diffolving and detaching the heterogeneous coloured particles." He further obferves, "it appears that the earth, which forms the folid fubftance of plants, is white; that it is feparable from the colouring matter by feveral means; that whenever it is either pure and unmixed, or diffufed through tranfparent colourlefs media, it exhibits its whitenefs, and is the only vegetable matter which is endued with a reflective power; that the colours of vegetables are produced by the light reflected from this white matter, and tranfmitted from thence through the coloured coat or covering, which is formed on its furface by the colouring particles; that whenever the colouring matter is either difcharged or divided by folution into particles, too minute to exhibit any colour, the folid earthy fubftance is expofed to view, and difplays that whitenefs, which, as before noticed, is its diftinguifhing character."

He ftates that in all thofe animal matters which do exhibit colours, the colouring particles are endued with the fame properties, and are regulated by the fame laws, which prevail in vegetable fubftances.

A reference to the original paper can only do juftice to the obfervations of this excellent philofopher, confirmed by numberlefs experiments; but what is already faid will be fufficient to give an idea of the nature of the procefs of bleaching, and that it depends on the removal of the matter interpofed betwixt the air and this white fubftance.

The national importance of bleaching is fo great, that it comprehends nearly the whole of the cotton and linen manufacture, and goes to an extent beyond moft other arts.

Its operation in thefe branches may be confidered under two points; viz. 1ft, the feparation of extraneous fubftances from linen and cotton, which is effected by fteeping, fermentation, or weak alkaline leys; 2d, the feparation of the conftituent or inherent colouring matters of thofe fubftances, which is effected by different modes, and by various modifications of each method, as expofure to the air, light, the ufe of alkaline leys, foap, oxygenated muriatic acid, combinations of oxygenated muriatic acid with other matters, fulphuric acid, hepar fulphuris, &c.

To imprefs upon the mind the nature of the bleaching bufinefs, it will be proper firft to defcribe the veffels ufed in the fundry operations of fteeping, boiling, bucking, wafhing, fouring, &c. then proceed to fhew the management of each procefs, with fome obfervations on its effects; and, laftly, how to make or procure the articles neceffarily employed in this art, and the method of afcertaining the qualities of each, adding fome obfervations on the theory of the operations.

BLEACHING of goods, particularly cotton manufactures.

1ft, *On Steeping.*

The veffels generally ufed in bleaching are made of fuch wood as will not communicate any colour to the liquors they are to contain, and therefore deal or fir wood is preferable to moft others. The veffels employed for fteeping the goods when received from the loom are ufually of the form A, *fig.* 1. *Plate* I. *Bleaching*. The goods when received from the weaver contain not only the natural colouring matter of the cotton, which is of an oily nature, and which prevents the cloth from eafily imbibing water, but alfo a fubftance called fowins, being a pafte made of flour and water, ufed during the weaving, and applied with brufhes upon the warp, in order to give a firmnefs to the threads by glueing

or

or pafting together the loofe fibres of the threads, and thus allowing them to pafs more freely through the reed and harnefs. To remove this fubftance, and to open the fibres of the cotton, fo as to give full effect to the fubfequent operations, it is proper to fteep the goods in a veffel of the above form in lukewarm water, till a gentle fermentation takes place, which will ufually be effected in 24 hours. The cloth fhould then be taken out, and well wafhed in a current of clear water, which will thus feparate a confiderable quantity of filth without the expence of ufing alkaline leys; and the cloth is then ready to be boiled or bucked as may be preferred by the bleacher.

2d, *On Boiling*.

For boiling, a copper veffel is to be preferred, and the goods prepared, as above mentioned, by fteeping and wafhing, are put into the veffel containing hot water only, or warm alkaline ley; a winch is placed over the veffel, and the piece goods attached to the ends of each other, are, when put in motion by the handle of the winch, dragged or rolled over it till the whole are paffed; the winch is then turned with a retrograde motion, and the cloth gradually thus returned back, in order that every part of each piece may be thoroughly impregnated with the liquor, which is raifed to and kept at a boiling heat, as long as it appears to extract any colouring matter from the cloth; the goods are then taken out and well wafhed in water.

Fig. 1. *Plate* IV. fhews a fection of the boiling pan A, of copper, fet in brickwork B; the winch C, with its handle D; E, uprights of wood, on which the winch turns; F, a cock to empty the pan; G, the fire-place; H, the afh-hole.

The ufe of this procefs depends upon the properties which alkaline falts have of uniting with the oily and refinous matters which are either attached to or are a conftituent part of vegetable fibres, and which contain their colouring particles, forming with them a faponaceous matter, foluble in water, and by that means eafily extricated from the cloth.

3d, *On Bucking*.

As this is one of the moft general operations in bleaching, it will be neceffary to defcribe it more particularly. *Fig.* 1. *Plate* I. under the word *bucking*, fhews at A the form of the bucking tub or kier, in which the goods are to be laid; B is an iron boiler, in which the alkaline falts, as pot-afhes or pearl-afhes, are to be diffolved in boiling water; C is the fire-place, in which a fire is conftantly kept up; D is the afh-hole; E, a cock through which the boiling ley is let out upon the goods clofely placed together in the bucking tub, A. A fufficient quantity of boiling ley is let into the bucking tub, till all the goods in the tub are thoroughly impregnated with it; the ley liquor is then allowed to pafs by a cock at H into an iron veffel placed in the ground at F, and from thence raifed by the pump G into the iron boiler B, and thence returned hot again upon the cloth. This operation is continued for feveral hours, till the ley, by the feparation of the colouring matter in the cloth, acquires a colour almoft black, a very offenfive fmell, and nearly the confiftence of molaffes or treacle. The cloth is then taken out, well wafhed from its impurities, and, in the old mode of bleaching, it is then laid upon the ground to be whitened by expofure to the atmofphere, but, in the new mode of bleaching, is fubmitted to the action of the oxygenated muriatic acid, to procure a fimilar whitenefs. It may be proper here to notice, that the old and new methods of bleaching are yet much the fame as formerly, only in the fubftitution of the ufe of the oxygenated muriatic acid in thofe parts of the procefs, where a long expofure to the atmofphere was formerly employed after the alkaline leys.

The operation of bucking acts on a fimilar principle to that of boiling, but in a much more forcible manner, as a greater quantity of afhes is added in proportion to the water made ufe of, and more heat is received and retained in the large bulk of cloth placed in the bucking tub, which expands the fibres of the cotton, and admits the more powerful action of the alkali, as is eafily demonftrated by obferving the very dark colour of the alkaline leys which have been ufed in bucking, in comparifon with thofe which have been employed in boiling goods. To thofe perfons who wifh for a full and minute account of the abforption and power of heat, we recommend a perufal of count Rumford's interefting effays on the fubject of heat.

The black alkaline ley which remains after bucking fhould be preferved, as it will anfwer, after evaporating and calcining, as hereafter mentioned, to form again frefh alkaline falts of good quality. With a view to preferve as much of the ley as poffible, it will be adifeable to wring it out into a tub from the cloth or yarn, after it is bucked, by the method fhewn in *Plate* IV. *fig.* 3. where R R are two ftrong pofts, fixed firm in the ground, S T two wringing hooks, upon which the cloth U is twifted, to force out the liquor, by W, a winch handle, which turns the hook round on the poft R. The two hooks are kept at a proper diftance from each other, one by a collar at X, the other by an iron pin at Y, which runs through a hole in the fquare part belonging to the hook T, which fquare has feveral holes in it to bring this hook nearer to the hook S when required.

4th, *Souring*.

This procefs confifts in immerfing, for the fpace of twelve hours, or more, the yarn or cotton in a mixture of water and fulphuric acid (vitriolic acid), well incorporated; the proper ftrength of which mixture is about the acidity of lemon juice, and is ufually directed by the tafte. The four kettle fhould be made of lead, of a form which can be heated; the heat of the liquor fhould not be greater than the hand can bear with eafe. This four kettle fhould be half funk within the ground, as fhewn in *Plate* IV. *fig.* 2. where M is a fection of the fouring veffel; N, the level of the ground; O, the brickwork; P, the fire-place, which is a half circle, or arch, without any grate; I I I, a fpace filled with dry afhes, betwixt the lower part of the four veffel and the brick-work, in order to preferve the heat of the liquor in that part of the veffel below the furface of the ground; K, a brick hearth, on which part of the fire is made; L, a caft iron plate, bending in the form of the four kettle, which is intended to prevent the fire placed on the floor at P K, from acting upon the lead of the four veffel; Q, the fpace betwixt the veffel and brick-work, through which the fmoke goes to the chimney.

The conftruction of this apparatus is upon the fame principle as the warm vats made ufe of by the blue dyers, the intent not being to make the liquor boil, but to keep it at a degree of heat which the hand can long and eafily bear. There are no grate or bars neceffary in this fire-place, as the coals will burn with fufficient rapidity without them.

The goods may be put into this acid liquor either in a wet or dry ftate. The beft plan is to immerfe the goods in the evening in the acid liquor cold, let them remain covered with it all night, then in the morning make a fire and bring the liquor to a blood heat, in which ftate having a winch over the veffel, fimilar to that reprefented at C, *fig.* 1. give the goods a few turns over it, that every part of them may be expofed to the action of the liquor. The goods may then be lapped round the winch to drain a little, to prevent an unneceffary wafte of the acid liquor, and afterwards carried to the wafh-wheel, or river, to be well wafhed from

the acid, so that the cloth may be perfectly tasteless to the tongue. It is a remarkable circumstance, that cloth may remain immersed a very considerable time in a strong acid liquor without rotting, but that if exposed to the air or heat of a stove, if a very small portion of acidity remains in the cloth, it becomes so concentrated by heat, as to damage the cloth immediately; therefore too much attention cannot be paid to this point.

The use of the acid liquor above-mentioned is to dissolve any earthy or metallic matters inherent in the cloth, or which may have been communicated to it accidentally, or which it may have derived from the impurity of the alkaline salts used in the bucking or boiling.

A considerable quantity of the acid liquor may be preserved by passing the goods which have been soured through a tub of clean cold water, previous to washing them, and replenishing the sour kettle with this acidulated liquor, rather than water only.

5th, *Washing.*

After every operation in which acids or alkaline substances are used in bleaching, it is necessary that the goods should be well washed in clear water; it is therefore of the greatest consequence that the water of a bleach ground should be pure, and in considerable quantities, such, for instance, as is perfectly transparent, will not curdle with soap, nor yield any degree of blackness with powdered gall nuts, or, which is a more accurate test, with a tincture of galls by infusion in spirits of wine.

Various methods have been invented for the purpose of washing out the impurities of the articles to be bleached; such as cleansing them in a large current of water by shaking them with the hand in the stream, beating them on blocks of wood with a flat paddle, or hand brush, beating them on a large flat stone with long wooden levers, flatted underneath, passing them over winches placed above vessels of water, or rivers, as *fig.* 1. and 3. *Plate* II. passing them betwixt plain or fluted rollers, as *fig.* 5. and 6. putting them under fulling mills, or fulling stocks, as *fig.* 7. or within wash-wheels, as *fig.* 1. and 2. and by many other modes, few of which are equal, and perhaps none superior, to those of which engravings are here given, for doing the business simply, effectually, and with ease to the workmen; the latter point of which is of consequence to be attended to, as it will be universally found in every mechanical employment, that if the least additional labour or care is required from the workmen, however great the effects produced, prejudice or indolence will prevent their doing justice to the invention. Under these circumstances, the wash-wheel represented in *Plate* II. *fig.* 1, 3, 4, is the best machine for general use, and the least liable to occasion damage to the goods. The front of the wash-wheel represented at A, *fig.* 1. is supposed to be eight feet diameter, exclusive of the buckets B, shewn by dotted lines on its periphery, which give it motion from the water falling into them. This wheel is divided within into four parts or quarters, by the strong arms projecting from the shafts D, to the outer circle; in each of these separate quarters or boxes, represented by dotted lines, one or more pieces of goods which require washing, are put loosely folded together through one of the holes C, of 14 inches diameter.

Fig. 2. shews the back part of the said wash-wheel, which is made of solid planks, excepting a grate of slender iron bars marked R, which encircles the wheel underneath the separation boards or bottoms of the buckets; the use of this grating is to admit within the wheel a current of clear water from the pipe Q. When an equal number of piece goods have been introduced into each of the four divisions of the wheel by the holes, C, &c. above mentioned, a current of clear water is permitted to run through a cock from the pipe Q, against the grating R, which allows it to flow freely through into the boxes, or those parts of the wheel which contain the goods; a valve is then opened from the trough P, communicating with a large reservoir or stream of water, a sufficient quantity of which is let into the outside buckets from the valve, to give the proper motion to the wash-wheel containing the goods. In every revolution of the wheel, the goods in each quarter of it are thrown twice, by the simple motion of the wheel, with great force against the arms which form the four divisions of it; viz. once in going down, and once in rising up. The ear can distinguish by the firmness of the sound when the wheel moves with proper velocity; and a greater or less quantity of water is allowed to act upon the buckets till that is attained, which usually is when the wheel makes 15 or 16 revolutions in a minute. During the whole time the wheel is in motion, the stream of clear water from the pipe Q flows upon the goods within the wheel in every direction; and the dirty water, produced from thus washing the goods, runs out of the wheel from a number of holes bored through the wood-work near the axle, and a few made in the front near the outer circle of the wheel. *Fig.* 4. shews an end view of the wash-wheel, about thirty inches wide, with the manner that the bucket-work is made.

It has been found to answer equally well to make use of a greater number of wash-wheels of a smaller size, as six feet diameter and two feet wide, of which several may be put in motion at once by a large water-wheel, horses, or a steam engine.

The goods, when taken out of the wash-wheel, are to be unfolded, and taken to the river to be streamed, or may be washed from any impurities which may remain in the folds by means of a winch N, *fig.* 1. and 3. *Plate* II. where six pieces of cloth are represented in the action of washing in a large wooden back divided into six partitions, to prevent the pieces of goods entangling with each other. *Fig.* 1. is a side view of the operation, where the dotted lines represent the partitions which separate the goods; I, a trundle wheel, which being put in motion by the cogs, H, of the wash-wheel, turns the winch on its axle, which winch may at any time be detached from it by the handle M drawing the catch K from the hook, as is shewn in the top view *fig.* 3. where also is explained, at the letters OOOOOO, the manner in which each piece of goods is kept in its proper place on the winch, by the partitions above mentioned, and by angular slips of wood nailed to the back and partitions.

To assist the drying of the goods after washing, they are usually passed betwixt two small rollers, commonly called squeezers, represented at *fig.* 5, where G is a solid wooden frame, containing two wooden rollers, each from 10 to 16 inches long, on an iron axis, which rollers receive a proper pressure by means of the two screws T acting on an iron bar V, which rests on the two ends of the axis of the top roller, as shewn by the dotted lines. In proportion as the screws press the iron bar upon the axle of the top roller, it brings that roller closer in contact with the bottom roller, and occasions more water to be pressed out of the cloth, which is passed betwixt them loosely drawn together, something like a rope, and the goods therefore require less time in the subsequent drying. In this plate the squeezers are connected with the wash-wheel above mentioned by a square iron socket, which, as is shewn at F, slides occasionally upon the squares of both axles. *Fig.* 4. shews at S the buckets of the wash-wheel, on which the water falls to give it motion; H, the cogs round its axle, which work the trundle wheel I.

Fig. 6. *Plate* II. shews two views of another machine used for cleansing cotton goods, consisting of two fluted or

grooved rollers, in the section of which *a* represents the sills, or bottom timbers; *b b*, the two supports or side pieces; *c*, one of the upright pieces in which the axles of the rollers are placed; *dd*, the two cross pieces to secure the frame work below; *e e*, the two rollers with grooved channels which fit to each other; *h*, one of the levers, which, from a point *i*, shewn by dotted lines, presses on the round end of the axle of the top roller, more or less, according as the weight *k* is placed on the lever further from or nearer to the axis of the roller.

In the geometrical elevation of the same machine, *ee* shews a front view of the two rollers; *f g*, the winch to turn it, with a hollow wood handle upon the iron work; *l*, the axis of the upper roller projecting beyond the side timber, so as to admit one of the levers *h* above mentioned to press upon it.

The wet goods, by being passed backwards and forwards through these fluted rollers, which are constructed at a much less expence than wash-wheels, are considerably cleansed, but not so perfectly as by the wash-wheels above mentioned.

Fig. 7. *Plate* II. explains another mode of cleansing goods, and is applicable to cotton, linen, or woollen goods, but more generally to the two last, as, without great care in its management, it is very apt to tear or damage cotton goods. This machinery is usually termed falling stocks, or falling hammers. N° 1. is the axle of the water-wheel, in which are fixed tappets at 2, to raise alternately the levers 3, 4, furnished with large wooden mallets or hammer heads 6, 8, channelled at the lower part as at 8. These lever hammers or fallers, work from a pin fixed in the upright at 7; 9 is a strong piece of timber hollowed out at 10, to receive the goods to be cleansed; 11, a piece of timber fixed a-slant to keep the fallers in their proper place, and direct their motion; 12, a chain fastened to each faller, serving by means of the hook 13, to suspend the faller whilst the goods are put in or taken out of the cavity 10.

When the goods to be cleansed are placed in a loose bundle in this cavity, the hammers are let down upon them, and put in motion alternately by the tappets 2, in rotation, which raise the levers to a certain height, and then quitting them, the hammer heads by their great weight, fall with great force on the goods in the cavity below them; and a current of clear water being admitted upon the goods from a cock above them, the dirty water runs out at a hole in the bottom of the cavity. The falling of the hammers gives a slow circular motion to the goods in the cavity, so as to expose the several parts in rotation to the action of the hammers.

Having noticed the vessels made use of in bleaching, and the general nature of the several operations, we shall now proceed to mention the origin of the several improvements made in this art, and their application to practice.

Under the operation of steeping, we have shewn the method of removing the colouring matters not natural to the vegetable, but acquired in the manufacture, and which may probably be best done by water alone, though sometimes some of the old leys, which have been previously used to other cloth, are employed to this purpose. After the steeping, and indeed after every application of bleaching agents, it should be laid down as a general rule, that the cloth or goods be carefully washed in cold water.

In the old method of bleaching, alkalies, such as pearl or pot-ashes, were, after steeping, applied by bucking or boiling, with alternate exposure to the atmosphere.

Alkalies acting so important a part, it is necessary to describe the bleachers' mode of using them, which consists in dissolving them in clean water, and thus forming what is termed an ash-ley. To which the more intelligent bleacher, if he does not make use of American pot-ash, or that of a similar quality, adds ⅓ of quicklime, whereby the ashes are rendered caustic, and their power materially augmented. But in order that no inconvenience may arise from causticity, after mixture, the whole is allowed to settle, and from the pure liquor thereof the work is afterwards supplied; the bleacher, in drawing it off, reducing it by the addition of water to the different strengths which the goods may require.

The ley being prepared, the bleacher proceeds to apply it to the cloth by bucking or by boiling.

In bucking, the alkaline ley is put into the boiler before described, near to and below which is the wooden vessel called a kier, in which the goods are loosely and regularly arranged. After this, a fire is put under the boiler, and beginning whilst the ley is yet cold, it is made to circulate through the cloth in the kier, from which it runs into the iron vessel placed in the ground, from this it is pumped up into the boiler, and again returned upon the cloth in the kier; and this circulation is maintained, and the heat at the same time increased, until the ley be so far concentrated by evaporation, as at last to remain almost wholly in the cloth. This is generally the operation of a day, and the cloth is allowed afterwards to remain thus impregnated with the concentrated ley until next morning.

In boiling in alkaline leys, the mode of which has been before described, the operation is continued from one hour to five or six hours, but it is more tedious and less effectual than bucking, where much business is to be done.

After bucking or boiling, the goods were, by the old bleaching process, exposed for at least a week to the air, before they were again submitted to the action of alkaline leys, and this process alternately repeated many times, till the goods were perfectly white, and the goods at last soured and washed off.

To explain the *old method of bleaching* more particularly, we shall add the following process for bleaching linen cloth.

Steep your raw linen cloth in a wood vessel all night, then change the water, and add fresh till you perceive the water to be no longer discoloured by it; rinse, wring, and lay it on the ground, and water it if you have opportunity. When it has thus lain on the grass three or four days, and is dry, take hold of each piece one after the other by the selvedge, and draw the cloth to you, still holding it in the most even manner you can, until you get the further end, with the corners of which further end you tie the cloth very loosely in the middle of the folds, and so lay it in the bucking tub, with the two selvedges upwards.

Thus proceed till you have placed as much cloth in your tub as will cover the bottom of it, taking care not to pack the cloth so close but that your ley may penetrate every part equally. When you have laid the first range of cloth in your tub, pour upon it as much milk-warm ley as will sufficiently soak through all parts of your cloth. Then lay another range in the same manner upon the first, and pour on more ley till that be soaked as the other was, and continue so to do till your bucking tub be full of cloth.

That done, you must begin to buck for twelve hours together, the remainder of your ley having been put in the pan with a slow fire underneath. For the first five hours the ley should not be of a boiling heat; you must from time to time allow some of the ley to run out of the pan upon the cloth in the bucking tub; then increase your fire gradually and slowly, so as in four hours more to bring it to a boil, continuing to put on the ley, and draw it off your cloth in small quantities at a time. When your ley begins to boil, you must let it boil on for three hours, during the whole

time pumping your ley up to the boiler from the reservoir, into which it runs from the cloth, and returning it boiling hot upon the cloth, so that the hot ley may act powerfully and equally upon every part thereof.

After each bucking your cloth must be laid upon the grass in the bleach-field for some days. The bucking, and exposure on the ground, must be repeated about ten times successively, according to the nature of your cloth; it should then be dried up, soured, and washed well in clean water; if the water is rather warm, the better.

Your two first buckings ought to be from a strong caustic ley of pot-ashes; but afterwards you should abate of that strength, lest it should injure your cloth. Mild ley, or pearl-ash, should be used for the latter buckings, as the cloth becomes nearer white.

This was the management during the summer months; but for four months in winter bleaching was suspended, the operations being periodically interrupted, and the capital of the manufacturers or proprietors of the goods locked up. Even during the bleaching months, their property was long in preparing for sale; as cotton goods, which required from four to six applications or repetitions of alkaline leys, consumed so many weeks in bleaching, whilst linens, which could not be bleached by less than from twelve to twenty applications, could not be brought in a marketable state to the proprietor hardly in six months.

Such was the state of bleaching till Mr. Scheele, a Swede and eminent chemist, discovered the properties of oxygenated muriatic acid, procured by mixing manganese with marine acid, in rendering vegetable matter white; and M. Berthollet, the celebrated French chemist, improved this operation, and actually applied its powers in bleaching cotton goods by interposing its action between the different alkaline operations instead of the tedious exposure of the goods to an uncertain atmosphere; the same effect being produced by immersion of the cloth in this acid, as by laying the goods upon the grass in the bleach-field, exposed to air and light.

Discovery of and Variations in the Mode of procuring the Oxygenated Muriatic Acid.

By the addition of vitriolic acid to common salt, an elastic aeriform fluid, or muriatic gas, is disengaged, from which with water a marine acid is produced. The mineral substance manganese, or what the modern chemists call oxyd of manganese, contains what was formerly denominated vital air, pure air, or dephlogisticated air, but now named oxygen. Manganese yields oxygen, when marine acid is added to it, and submitted to distillation; the liquor produced by the contact of this oxygen with water, is the oxygenated marine or muriatic acid discovered by Mr. Scheele, about the year 1774, when he observed and applied its effects in rendering colourless vegetable substances of various kinds, more as a matter of curiosity than use.

M. Berthollet, in the year 1786, improved the process of its preparation, applied its power to bleaching or destroying the vegetable colours natural to cloth, the result of which experiments he gave to the world in the year 1789; but, without derogating from the merit of this excellent chemist, it is justice to state, that, previous to any publication by M. Berthollet, Mr. Scheele commuuicated to M. Kirwan the properties of the dephlogisticated marine acid in whitening vegetable substances, and Mr. Kirwan, then residing in Newman-street, London, suggested to Mr. C. Taylor, the present secretary to the Society of Arts, &c. the probability of its use in bleaching; and a whole piece of callico, in the state received from the loom, was, in the spring of 1788, actually bleached white, printed in permanent colours, and produced in the Manchester market ready for sale, having undergone all these operations in less than 48 hours, by the joint efforts of Mr. Cooper, Mr. Baker, and Mr. Taylor, which is perhaps the first entire piece, either in France or England, that fully ascertained the real merits of the new mode of bleaching, and a certainty that it might be generally useful in commerce. This experiment was immediately followed by the establishment of a large bleaching concern by Mr. Cooper, Mr. Baker, and Mr. Horridge, at Raikes, near Bolton, in Lancashire, and before any considerable bleaching work was actually at work in France.

The ingenious Mr. Watt we believe to be the first person who simplified the process of preparing the oxygenated muriatic acid, by means of a mixture of common salt and manganese, previous to the addition of the vitriolic acid. Soon afterwards the operations of the bleacher were farther facilitated by the substitution of large and commodious stills of lead, instead of glass vessels, and both these improvements have since been in general use.

We shall now proceed to mark the various treatment of the oxygenated muriatic acid when obtained, and the different means which have been adopted to fit it for application in bleaching.

It having been found in the earlier stages of distillation, that common marine acid was produced instead of the dephlogisticated or oxygenated muriatic acid; and from the violence of the ebullition, that manganese itself was sometimes thrown over from the still, M. Berthollet had recourse to an intermediate vessel, containing water, to absorb the marine acid gas, and stop other impurities which might contaminate the oxygenated muriatic gas in its passage through this vessel to the receiver.

It will here be necessary to discriminate the various modes in which the oxygenated muriatic gas has been treated, after passing the intermediate vessel last mentioned.

Mr. Scheele seems generally to have operated with the acid in the state of gas; but M. Berthollet sought to condense it in water, with which he filled his receiver, or wooden vessel, and which water he kept agitated during the distillation, to accelerate the solution or combination of the gas.

The oxygenated muriatic acid, thus prepared, was drawn from the receiver into kiers, or large wooden vessels, where its strength was regulated by the addition of water; after which, the goods to be bleached were immersed therein from six to twelve hours, but most frequently during the night; and though these periods may seem short, they were sufficient to allow the cloth to become more white than could be done by as many days' exposure to the atmosphere and a summer's sun, and were then ready for a fresh application of the alkaline leys.

Such was the bleaching liquor of M. Berthollet; but it was found in practice yet defective, as the volatility of the gas occasioned its speedy separation from the aqueous solution; a decomposition even by light alone in glass vessels took place; a rapid loss in the strength of the liquor when exposed; and much danger to the health of the workmen from its suffocating quality; at the same time, that in extracting the natural colours of the cloth, it also tended to discharge the colours dyed in the yarn, and were along with the gray cotton an imperfection which precluded its use in an infinite variety of British manufactures.

Similar circumstances probably led some bleachers resident at Javelle, in France, to add a solution of caustic alkali to the water in the receiver, and by this means to remedy many of the defects complained of.

But M. Berthollet continued to recommend his process, considering such substance as impairing the bleaching powers;

an idea that was generally maintained by the chemists, but contradicted by the bleachers, whose experience taught them, that though the acid thus combined whitened with somewhat less rapidity, yet it was not eventually in an inferior extent; and the advantages of preserving the colours dyed in the yarn, compelled them to have recourse to the expensive addition of pot-ashes, in preference to M. Berthollet's mode.

Here we shall observe, that, according to the doctrine of the modern chemists, the oxygenated muriatic acid bleaches in consequence of yielding to the colouring matter of the cloth that oxygen which, in the distillation, the acid absorbed from the manganese; or, in the language of Stahl and Becher, that the dephlogisticated marine acid absorbed the colouring matter from the cloth, and was restored to its original state of common marine acid, by regaining that phlogiston which it had, in its preparation, yielded to the manganese.

In the mixture of an alkali with the acid, we have noticed that the bad consequences arising from its volatility have been corrected, and the requisite protection afforded to dyed colours, yet still that its power of whitening cloth was not diminished, nor much more time taken up by the operation; yet, in part from deference to M. Berthollet's opinion, and in part owing to the expence of the alkali, other means to produce the effect were attempted.

One of the first of these, practised by the bleachers of cotton-hose, at Nottingham, was to receive the dephlogisticated muriatic gas into a small air-tight chamber, in the upper part of which the goods were suspended from a frame, whilst at some distance below was water, sometimes impregnated with ley of pot-ash, and sometimes with lime-water, or water mixed with lime. The gas was introduced betwixt the fluid and the goods, amongst which it ascended and mixed; at the same time, by occasionally immersing the goods in the fluid below, it was sought to modify the action of the acid. This was effected by means of a pole, or long lever, connected with the frame on which the goods were suspended, the centre of which pole moved on a swivel fixed in a hole in the partition, occasionally stopped with clay, and enabled a person to let the goods down into the fluid, not always however without inconvenience, which occasioned it the name of the *Bedlam Process*.

Respecting the above process it must be observed, that the acid is much more powerful or active in the state of gas than in any other way; and though the occasional immersion of the goods into the fluid below, corrected in some degree its violent effects, yet the dyed colours disappeared more rapidly in this than in any other process, and the fabric itself was sometimes injured.

The next process attempted by the bleachers, was to put into the receiver, filled with water, a quantity of pulverized lime, then the goods themselves, and the whole agitated during the admission of the gas; the consequence of which was, that the goods thus mixed with lime were partially coated with it; and this coating being unequal, the action of the acid upon it was irregular, leaving at the same time the parts uncoated to receive the whole action of the bleaching powers; hence inequality of bleaching ensued, and an insurmountable difficulty in preserving the dyed colours of the goods to be bleached.

Having noticed the imperfections of the two last processes, we shall observe that lime-water, or a pure chemical solution of lime in water, has been sometimes substituted instead of a solution of alkalies in the receiver, but was not, when used in that manner, found to answer so well as the alkaline solution.

That lime-water could produce no valuable effect beyond what was derived from M. Berthollet's mode, or from simple water, must be evident, when it is considered that water can dissolve no more than $\frac{1}{700}$th part of its weight of lime, a quantity wholly insignificant in neutralizing the oxygenated muriatic acid for the purpose of the bleacher; nor could pulverized lime, merely thrown into the water of the receiver, serve a better purpose, since, from its being specifically heavier than the water, all beyond the quantity in chemical solution subsided and remained nearly useless at the bottom of the receiver.

It has been already mentioned, in noticing the application of alkaline leys in bleaching, that the more intelligent bleachers, in preparing their ash-leys, made use of quicklime to augment the power of the alkali, when such alkali was in a mild state, or, in other words, combined with fixed air, or, as it is now termed, carbonic acid; the attraction of caustic lime for the carbonic acid being stronger than that of ashes. Hence, on caustic lime being thrown into mild ash-ley, the carbonic acid, by which the ashes were rendered mild, abandons the alkali to combine with the lime, leaving the ashes in their caustic state.

But, although the attraction of carbonic acid is stronger for lime than for alkali, the contrary is the case with the oxygenated muriatic acid, as it abandons lime to combine with ashes, leaving the lime to precipitate.

This observation is made in order to guard the ignorant bleacher from mistakes, who, from having mixed lime with his ash-ley in the receiver, in the preparation of the oxygenated marine acid, may suppose it acts in a similar manner; but not a particle of lime is acted upon by the acid, whilst ashes remain to combine with it; the only effect of the lime there, being to abstract from the ashes any fixed air they may contain, and so dispose the alkali to absorb more of the oxygenated muriatic acid.

Besides the processes above mentioned, the bleachers attempted to unite the oxygenated muriatic acid with clay; but as the clay has scarcely any affinity with it, the liquor thus made was little, if at all, superior to that of M. Berthollet.

Such were the attempts made from the year 1786; and the oxygenated muriatic acid combined with pot-ash was in general use by the bleacher until 1798, when Mr. Tennant, of Glasgow, by a well-conducted series of experiments, formed what may not improperly be called a new æra in bleaching.

Mr. Tennant, having seen so long a period elapse without any material improvement in bleaching, and the alkali, though an expensive ingredient, regarded by the bleacher as an indispensible article to unite with the oxygenated muriatic acid in the receiver, made some trials with the earths strontites and barytes, and with success. Their solubility in water enabled him to combine them with a sufficient quantity of oxygenated muriatic acid to serve the purpose; but the scarcity of strontites, and the difficulty of separating barytes from the vitriolic acid, with which it is usually found in combination, rendered these discoveries rather objects of curiosity than use.

Mr. Tennant had previously made experiments to combine the oxygenated muriatic acid with lime and lime-water, in the modes above-mentioned, but found they were not adequate to the purposes intended; the lime in general remaining at the bottom of the receiver uncombined with the gas, which was the necessary consequence of the lime being specifically heavier than the water, and the gas much lighter; the water, by its interposition betwixt the two substances which ought to be combined, namely the oxygenated muriatic gas and the lime, preventing their union. To bring the pulverized lime into contact with the gas as quickly as

it entered the receiver, became then the object of his attention; and for this purpose he found it was necessary to keep the lime floating, or diffused through the fluid, which he succeeded in accomplishing by two different methods; one of which was by increasing the specific gravity of the water in the receiver, by the addition of common salt, and thus retarding the lime from subsiding; the other mode was by constant agitation of the lime in the water in the receiver, to keep the lime diffused through the fluid, during the time the oxygenated muriatic gas was introduced; and by this means he succeeded in uniting and retaining a much greater quantity of gas with the mixture, than by any method heretofore used, and without the addition of any ashes or alkaline substances.

A very material advantage was gained by this discovery; namely, that it uniformly afforded security to the dyed colours in a superior degree to the alkaline ley.

It is well known, that in the alkali of commerce, such as pot-ash or pearl-ash, a large and very irregular proportion of neutral salts is intermixed, which are soluble along with the alkali in water, thereby so far contaminating the ley, that the bleacher is always uncertain what quantity of pure and active alkali it contains. In bucking or boiling cotton goods, the detriment from these neutral salts is not so great, as a repetition of the process may compensate for those admixtures in the ley: but in the bleaching liquor formed by the mixture of the oxygenated muriatic gas with such ley, if there is a deficiency of alkali, the uncombined oxymuriatic acid immediately attacks the dyed colours of the goods, and discharges them, and thus considerable damage frequently occurs before the real origin of the evil is ascertained and corrected. The bleacher is kept in a constant state of alarm respecting the quality of the ashes he makes use of, besides the great cost of their purchase. In using lime for the same purpose, the expence is a mere trifle; what is not combined with the oxymuriatic acid precipitates, after the agitation is over, leaving a pure liquor free from all uncombined acid.

Simple as the combination of the lime with the oxygenated muriatic acid may now appear, yet it was a long time attempted in vain; but this, perhaps, will not be such a matter of surprize, when we reflect that the French chemists, whose opinions were regarded generally as law by the common bleachers, and whose treatises on the subject of bleaching were almost the only accounts published, considered lime as no farther useful in bleaching, than in absorbing the carbonic acid or fixed air usually combined with alkalies or ashes; and thus rendering the alkaline ley more disposed to unite with the oxygenated muriatic gas, when exposed to its contact in the receiver, to form, as it is called, the liquor de Javelle; or when intended for use as a mere alkaline ley, to render its action more powerful on the oily particles in the vegetable fibre, on a similar principle to the formation of soap.

An excellent treatise on the subject of bleaching, in the English language, viz. "The Report on Experiments made by order of the right honourable the trustees of the linen and hempen manufactures to ascertain the comparative merits of specimens of oxygenated muriatic bleaching liquids," published at Dublin in the year 1791, in claim of a bounty offered by the trustees, appears to convey no further knowledge of the use of lime in bleaching at that time than in promoting the separation of the carbonic acid from the leys, whether they were afterwards to be used alone, or in the preparation of the oxygenated muriatic acid. Mr. Rose's experiments in this report contain, however, much useful information, which we shall further notice.

The simplicity of Mr. Tennant's invention of retaining a greater quantity of the oxygenated muriatic gas, by agitation of a sufficiency of lime in the water of the receiver, should be no derogation to its real merit. In substituting lime for pot-ash, an article, not only of foreign produce, but expensive, he has benefited this country, to an extent almost beyond conception; it having been proved upon oath, that by the use of Mr. Tennant's process, the consumption of ashes at a single bleaching-green has been reduced three thousand pounds sterling in value in one year. A patent for Mr. Tennant's invention was granted him in the year 1798; but as frequently happens in patent causes, on a late trial of its validity, some circumstances arose from which the jury thought themselves justified in reversing the patent; we have therefore with considerable pains collected for the public benefit an account of his process, and the most approved mode of putting it in practice, either on a small or an extensive scale, as will be seen by a reference to *Plate* I. of *Bleaching* hereafter described.

Mr. Tennant's method of using calcareous earth for neutralizing the muriatic acid gas, and forming the oxy-muriat of lime employed in bleaching is as follows; viz.—In a receiver capable of containing one hundred and forty gallons wine measure, dissolve thirty pounds of common salt, which appear useful only in giving an additional degree of specific gravity to the water, and by that means making it easier to keep the lime to be afterwards added, in suspension; when this salt is dissolved, add sixty pounds of finely powdered quicklime, and into the retort of the apparatus put thirty pounds of powdered manganese, mixed up with thirty pounds of common salt, upon which pour thirty pounds of sulphuric acid (oil of vitriol), previously diluted with its bulk of water, and the usual precaution of luting the vessel being taken, proceed to distillation. When the gas begins to appear, the agitation of the lime and water in the receiver must commence, which should be continued by means of a wooden paddle or rake, or similar contrivance, without intermission, until the materials in the retort, after heat being employed as usual, will not yield any more oxygenated muriatic acid gas. Then the whole should be allowed to remain at rest for two or three hours, when the clear liquor in the receiver, may be drawn off for use, and mixed with water in such proportions as may be found necessary, previous to the immersion of the goods to be bleached.

The principal point of attention in preparing this oxygenated muriat of lime is, to obtain a complete diffusion of the lime through the mixture, or a mechanical suspension of it in the water during the operation, so that every particle of the lime may, by agitation, be exposed to the action of the gas, instead of merely its upper surface, as had been formerly practised. By the present means, the oxygenated muriatic acid gas is absorbed with ease, and meets with a sufficient quantity of lime to produce a strong solution of oxygenated muriat of lime, without any uncombined oxygenated muriatic acid; a thing which could not be otherwise effected. The addition of the common salt in the receiver may even be omitted, without prejudice, if the agitation of the lime be well managed.

Plate I. *fig.* 2. of *Bleaching*, shews a longitudinal section of a method, which has been practised in Ireland for distillation of the oxygenated muriatic acid, and the formation of the oxygenated muriat of lime. *a*, the ash-hole; *b*, the fire under the iron pot or vessel; *c*, the aperture through which it is supplied with coals; *d*, the entrance to the ash-hole, which may be provided with a stopper of burnt clay, or earthen ware, to regulate the draught of the fire, by means of the handle shewn by dotted lines: *e*, a cast-iron pot or

vessel, nearly filled with water, in which the leaden retort is placed; *f*, a tripod of iron, on which the retort stands; *gg*, the leaden retort, from which the gas is to be distilled; *h*, a tunnel of bent lead, through which the oil of vitriol (sulphuric acid) is to be introduced into the retort; *i*, a leaden cover, fitted and luted to the neck of the retort, having three apertures, viz. for the introduction of the tunnel, the rod of the agitator, and the tube of the condenser; *k*, the agitator, formed of a rod of iron coated with lead, having some arms at its lower end to stir the materials within the retort. At the part where the rod passes through the cover, a leaden collar or cap is soldered, to prevent the agitator from descending too low; these two parts are made in a conical form, to fit exactly, and thus prevent the escape of the gas; *l*, a leaden tube or pipe, of three inches bore, to conduct the gas into the tubulated reservoir; *m*, the leaden reservoir, formed upon the principle of Wolfe's apparatus; the tube, *l*, descends by the first aperture, *m*, to the bottom of the reservoir, which is about two thirds full of water. The small portion of sulphuric acid, which rises in distillation, unites with this water; the oxygenated muriatic acid, which traverses this water, passes by the pipe, *n*, into the receiver or condenser, *oo*, which is a wooden vessel, in the midst of which is placed an agitator, *p*, the arms of which raking up the lime cause it to combine with the gas, in proportion as it arises in bubbles from the lower extremity of the leaden pipe, *n*.

The projections of wood, *qqqq*, fixed to the staves within the tub, counteract the rotatory motion of the arms of the agitator, and thus assist the combination of the gas with the lime and water. The cover of this tub is fixed close upon the edge of it at *r*; the cover having a groove in it to unite them tighter together; *s*, a cock to draw off the liquor, when sufficiently impregnated for use; *t*, a wooden handle to give motion to the agitator. The joints may be luted with clay, to prevent the escape of the gas.

Fig. 3, and 4, shew Mr. Tennant's improved machinery for preparing the oxy-muriat of lime. The outline, A, (*fig.* 3.) is the still, made of lead, of a circular form, having a double flange at the top, which is filled with water, to prevent the gas from escaping in that direction. B, the leaden cover of the still, having a flange on the under side, which goes into the double flange of the still, and having a double flange on the upper side, which is filled with water; the inner part of this double flange consists of a short tube, which goes quite through the cover, opening by this means a communication with the still, and allowing the gas to escape through the long leaden pipe inserted into it, and from thence into the receiver, as explained at *fig.* 4, where there is a section of the still, furnace, and receiver; *a*, the still; *b*, an iron pan in which the still is placed on an iron stand; this pan is then nearly filled with water; *c*, the fire-place; *d*, the furnace door; *e*, the ash-hole; *f*, double flange filled with water; *g*, the cover, with flanges on the upper side filled with water. D, the receiver, made of wood, and lined with lead; *i*, a double flange filled with water, the interior pipe communicating with the inside of the receiver, and bent horizontally as at *l*, from whence the gas issues into the receiver; *l*, *l*, two short pipes inserted in the top of the receiver, through which the rods of the agitators have a free motion; *m*, *m*, a stopper in the top of the receiver, closed when the receiver is at work, but sufficiently large, if removed, to admit a person into the inside to repair or cleanse it, when necessary; *n*, *n*, two paddles, or agitators, generally of a square form, and of a similar construction to the head of a churn staff; *o*, *o*, the rods of the agitators attached by iron pins to the lever, *q*, which lever has slits at the place of junction, to allow the rods to rise and fall perpendicularly; *p*, the fulcrum or support of the lever; *q*, the lever, which, by a proper motion communicated to it, alternately raises and depresses the agitators in the receiver; *r*, a rod connecting the lever *q*, with the lever *s*, which last lever is put in motion by the wheel E; *t*, a balance weight placed at the other end of the lever; the beam supporting the fulcrum of the lever being near the letter *s*. E, the wheel to be put in motion by water, or in any other way, having a crank, *u*, communicating by an upright shaft with the lever *s*.

It will be found that the flanges, filled with water, preclude the necessity of the application of any lute, and occasion the operation to be conducted in a cleaner, cheaper, and more expeditious mode, than formerly employed.

To describe the proportions of the several articles used in the process of bleaching, would carry us far beyond the bounds which can be allotted in the present publication; we shall, therefore, give the following short but clear account of the mode we recommend to be practised, to procure the most perfect and durable white on cotton goods, after their being taken from the weaver; which is, first, to wet them thoroughly in cold water; then to allow them to steep in cold, or lukewarm water, from 12 to 36 hours, according as they are of a strong or thin fabric; then to wash them well in clean cold water; afterwards to buck or boil them in a caustic alkaline ley; then to wash the goods well in clean water, and afterwards immerse them in diluted oxymuriate of lime, and wash them, repeating the operations of the alkaline leys, and the oxymuriate of lime, till the goods are perfectly white; then to pass the goods through the diluted sulphuric acid liquor, washing them well afterwards; lastly, to pass them through a weak ley of pearl-ashes, or of soap, and again through clean water, before drying and finishing them; which finishing of the goods consists in starching, blueing, rolling, or callendering them as fashion directs, or the particular market for which they are intended, may require.

It is to be remarked, that the immersion of the goods in the vitriolic sours, and also in pearl-ash, or soap liquor, is necessary at the end of the process, to prevent a brown hue which the cloths that are bleached white from the oxygenated muriatic acid, without such precaution, are apt to revert to.

By experiments made at Rouen on cotton thread, with a view to ascertain whether the old or new mode of bleaching was more prejudicial to the fabric, it was proved that the cotton thread bleached in the new mode bore, without breaking, considerably more weight than that bleached in the old method, and was less injured in texture.

In the report on experiments, made by order of the trustees of the linen and hempen manufactures at Dublin, in the year 1791, with a view to ascertain the comparative merits of several specimens of bleaching liquids sent for their examination, the following mode of bleaching appeared to be the best for linens, and though executed on a small scale, will convey the principal necessary information.

May 11th, 1791. The linen was steeped, in the state received from the loom, into water of a heat sufficient to bear the hand, and left in the vessel.

May 16th. The linen was washed out of the liquor, in which a pretty strong fermentation was observed to have taken place.

May 17th. Finished making a mother-ley, which was made in the following manner: three pounds and a half of lime were slaked, and mixed with ten gallons of water; fourteen pounds of Dantzic pearl-ash were dissolved in some of this water; then mixed the whole; when it had settled, a

was filtered through a coarfe cloth, and the refiduum wafhed repeatedly in four gallons of water, to obtain the whole ftrength of the alkali; the whole fourteen gallons being then carefully mixed, the ley proved, by very accurate weighing, to contain twelve ounces of cauftic alkaline falt to the gallon. From this, a ley was made from the work, by adding fix parts of water to one of the mother ley; thus each gallon of the working ley contained one ounce, five drachms, and forty-three grains of cauftic alkali.

The boiler being charged with this ley, the linen, which had been fpittle wafhed, was fteeped in it cold for one hour; then brought up by a very gentle heat to a fimmering boil, which was continued for three hours; the cloth was then well wafhed out, and left in fteep for that night.

May 18th. Wafhed out the above linen in frefh water; hung it on cards in the open air, watering it feveral times in the day.

May 19th. Finding the cloth not fo well cleared as could be wifhed, the boiler was again charged with one of mother-ley, to four of water, which made the ftrength two ounces, three drachms, twelve grains of cauftic alkali to the gallon. In this was boiled another piece of linen which had been fpittle wafhed as the others; and after it was boiled, it was well wafhed out.

May 20th. Steeped the whole of the linens for fix hours in the liquid prepared with the oxymuriatic acid of the feveral claimants; afterwards wafhed them well out, and left them fteeping in cold water all night.

May 21ft. Wafhed out all the above linens, and when dry, boiled the whole parcel as before in one of the motherleys, to five of water, containing two ounces of cauftic alkaline falt to the gallon; wafhed them well out of the ley, and left them to fteep in pure water till Monday morning, the 23d inftant.

May 24th. Steeped the linens for the fecond time in the oxygenated muriatic acid for fix hours; then wafhed them out, and left them to fteep all night in cold water.

May 25th. Having charged the copper with a ley made from one of mother-ley, to fix of water, containing one ounce, five drachms, and forty-three grains of cauftic alkaline falt to the gallon, the linens were boiled in this for the third time, with a very gentle fimmering heat for three hours; they were then wafhed out, and left to fteep.

May 27th. Steeped all the linens for the third time fix hours in oxygenated muriatic acid as before; wafhed them out, and left them in water all night.

May 28th. Immerfed all the linens which had been fteeped yefterday in the oxygenated muriatic acid, in a weak vitriolic acid for four hours; then wafhed them out, and left them fteeping in cold water.

May 29th. Wafhed and dried the linen cloth which had been foured yefterday.

June 1ft. Boiled all the linen which had been foured in a ftrong lather of foap.

June 2d. Soured and wafhed out all the linen which had been boiled in a foap lather yefterday. This operation finifhed that experiment, in which the above linens were firft fteeped in water; then boiled in cauftic alkaline ley, and fteeped in oxygenated muriatic acid alternately four times; then foured in vitriolic acid, foaped and foured again.

The above experiments were made, with various others, by Mr. John Arbuthnot, and Mr. John Clarke; and on the trials of the different fpecimens of the oxygenated muriatic acid, the preference was given to that prepared by Mr. Robert Roe, of Bing's End, on the principle of the javelle liquor mentioned by Mr. Bartholles, by adding a folution of alkali in water in the receiver. Mr. Roe's beft preparation, of which was made by adding thirty-eight pounds of quicklime to 114lb. of pearl-afh, which made a cauftic ley of about nine pounds weight per gallon; he found cauftic ley more fufceptible of imbibing the gas and retaining it, than mild ley of equal ftrength.

From the different experiments made to bleach various articles at the above time, the following inferences may be deduced, viz. that allowing cotton or linen, when raw from the loom, to ferment, by fteeping in warm water a confiderable time before boiling the cloth in an alkaline ley, is of confiderable fervice.

That cloth or yarn is not injured by fteeping for fix hours together in oxygenated muriatic acid.

That ftrong alkaline leys anfwer better than weak ones, at the commencement of ufing the leys.

That the white colour of bleached cloth can be better judged of wet than when dry.

That very minute attention in excluding light and air is not abfolutely neceffary in bleaching with oxygenated muriatic acid.

That purging or clearing yarn or cloth in an alkaline ley, previous to fteeping in oxygenated muriatic acid, is abfolutely neceffary.

That the bleaching liquids made from oxygenated muriatic acid, in which alkaline falt is blended in the compofition, require the cloth to be frequently fteeped in vitriolic acid; and that the oxygenated muriatic acid made with water only, make more frequent boilings of the cloth in alkaline leys neceffary.

That the lofs of the cloth in weight, when bleached by the new method, is only one fourth, but by the old method one third.

That fteeping in warm water is infinitely better to extract the fowen and dirt from the raw cloths, than boiling them with foap or ley immediately as they come from the loom..

The liquors of the oxygenated muriatic acid, and alfo thofe made from the vitriolic acid, may be repeatedly ufed without detriment, till the whole ftrength is exhaufted.

The cloth or linen, in the acid bleaching liquors, fhould be moved in the liquor every hour, that every part may be equally cleared.

It is difficult to afcertain the ftrength of the leys proper for ufe in bleaching cotton or linen, as the alkalies or afhes differ fo greatly in purity, and the admixture generally found in them of neutral falts prevents the hydrometer from being a regular teft. The common allowance for bleaching linens in Ireland, is ftated by Mr. Higgins, in his ingenious memoir in the Tranfactions of the Dublin Society, to be for fixty gallons of water, fix pounds of barilla, or four pounds of pot-afh at the leaft, and moft bleachers ufe more than this.

To difcover adulterated pot-afh, Mr. Higgins recommends the following method. The fpecimen of afhes being firft weighed, is digefted for a few minutes on a fand-bath, in twice its weight of water, in a heat of about 212 degrees, and inftantly ftirred. It is then removed from the fand-bath, and before it is cooled to the temperature of the atmofphere, it muft be filtered through paper. When all the liquor has paffed through the filter, a fmall quantity of cold water is gradually poured upon the faline refiduum or the filter, in order to wafh through the whole of the alkali. The undiffolved falt fulphate of pot-afh (vitriolated tartar,) remaining on the filter, is afterwards dried and weighed, to afcertain the quantity.

To determine whether any common falt is fufpended in the liquor which has been filtered, evaporate the clear folution a little on a fand-bath, and fet it in a cold place for 24

hours; at the end of which time, any common falt it contains will be found cryftallized in regular cubes at the bottom of the veffel; pour off the clear liquor, and repeat the procefs, till no more cubic cryftals are produced. If it is defired to be very accurate in the analyfis, before the common falt (muriate of foda) thus procured is weighed, fome muriatic acid may be poured upon it, in order to take up any of the pure pot-afh which may have adhered during its cryftallization. The muriatic acid, with fuch of the alkali as it has diffolved, may be then drained off and thrown away, and the muriate of foda dried and weighed.

The fum of the impurities being then fubtracted from the weight of the fpecimen, the quantity of the pure pot-afh is afcertained.

To fhew what quantity of mere alkali is contained in 100lb. avoirdupois of feveral different alkaline falts examined by Mr. Kirwan, we fhall add the following table, publifhed by him in the Irifh Tranfactions, in 1789.

One hundred Pounds.		Mineral Alkali.
Cryftallized foda	yielded	20lbs.
Sweet Barila		24
Mealy's cunnamara kelp		3.437
Do. defulphurated by fixed air		4.457
Strangford kelp		1.25
One hundred Pounds.		**Vegetable Alkali.**
Dantzic pearl afh	yielded	63.33lbs.
Clarke's refined afh		26.875
Cafhup		19.376
Common raw Irifh weed-afh		1.606
Do. flightly calcined		4.666

It is much to be regretted that, confidering the immenfe quantities of pure marine alkali which could be procured at a cheap rate from the Eaft Indies, that fo little attention fhould be paid by the Eaft India company to an article which would be fo profitable a branch of commerce to them, and prevent a confiderable fum being paid to other nations. The mineral alkali procured from the Eaft Indies, is much purer than what is obtained from Barilla; and a preparation exactly fimilar in appearance and quality to the Alicant Barilla, may be made with great advantage to the manufacturer, from a mixture of the Eaft India mineral alkali with the common Scotch kelp, for the purpofes of the bleacher, the foap maker, or the Turkey-red dyer. To fhew the importance of this object, the following table of the imports into Great Britain are annexed for feven years.

	Barilla.	Pot-Afhes.	Pearl-Afhes.
1796	86.723 cwt.	62.829 cwt.	45.290 cwt.
1797	51.105	57.826	36.674
1798	123.990	81.482	60.691
1799	146.163	77.246	51.792
1800	175.629	135.400	45.161
1801	63.210	90.523	54.835
1802	151.796	48.054	64.288

When it is confidered that 20 pounds of the mineral alkali brought from India in a powdery ftate, as it ufually is, will, by mere folution in water, yield 100lbs. of the cryftallized foda fold in the fhops, it will be feen, that the purchafe of the mineral alkali from the Eaft India company, will be an object well deferving the attention of the bleachers and foap-boilers; and far preferable to the ufe of Spanifh kelp or Barilla.

Mr. Kirwan, by means of muriatic acid, precipitated the colouring matter from an alkaline ley, faturated with the colouring matter of linen yarn, and found it to poffefs the following properties. When fuffered to dry for fome time on a filter, it affumed a dark green colour, and felt fomewhat clammy, like moift clay. His obfervations in the Irifh Tranfactions for 1789, are as follow:

"I took, fays he, a fmall portion of it, and added to it 60 times its weight of boiling water, but not a particle of it was diffolved. The remainder I dried in a fand-heat; it then affumed a fhining black colour; became more brittle, but internally remained of a greenifh yellow, and weighed one ounce and a half."

"By treating eight quarts more of the faturated ley in the fame manner, I obtained a further quantity of the greenifh depofit, on which I made the following experiments:

1ft. Having digefted a portion of it in rectified fpirits of wine, it communicated to it a reddifh hue, and was, in a great meafure, diffolved; but by the affufion of diftilled water, the folution became milky, and a white depofit was gradually formed; the black matter diffolved in the fame manner.

2d. Neither the green nor the black matter was foluble in oil of turpentine or linfeed oil, by a long continued digeftion.

3d. The black matter being placed on a red hot iron, burned with a yellow flame and black fmoke, leaving a coaly refiduum.

4th. The green matter being put into the vitriolic, marine and nitrous acids, communicated a brownifh tinge to the two former, and a greenifh to the latter, but did not feem at all diminifhed.

"Hence, it appears, that the matter extracted by alkalies from linen yarn, is a peculiar fort of refin, different from pure refins only by its infolubility in effential oils, and in this refpect refembling lacs. I now proceeded to examine the powers of the different alkalies on this fubftance, eight grains of it being digefted in a folution of cryftallized mineral alkali, faturated in the temperature of 62°, inftantly communicated to the folution a dark brown colour; two meafures (each of which would contain eleven pennyweights of water), did not entirely diffolve this fubftance. Two meafures of the mild vegetable alkali diffolved the whole."

"One meafure of cauftic mineral alkali, whofe fpecific gravity was 1.053, diffolved nearly the whole, leaving only a white refiduum."

"One meafure of cauftic vegetable alkali, whofe fpecific gravity was 1.039, diffolved the whole."

"One meafure of liver of fulphur, whofe fpecific gravity was 1.170, diffolved the whole."

"One meafure of cauftic volatile alkali diffolved alfo a portion of this matter."

The colouring matter of cotton is much more foluble in alkali, than that of linen: hence the greater facility with which cotton is bleached.

The theory of bleaching vegetable matter, as we have before obferved to have been defcribed by Mr. Delaval, depends on removing the colouring matters, whether natural or accidental, which cover their folid fibrous parts, which are the only parts endued with a reflective power.

Raw cotton or linen, boiled in a a diluted folution of cauftic alkali, gives to the liquor a deep brown colour, and deftroys its caufticity; and frefh portions of clear ley applied a fecond or third time, will produce a fimilar effect, but in an inferior degree. If the cotton or linen be now plunged into the oxymuriatic acid, and allowed to remain a fhort time, they will become white; and if they are then plunged into an alkaline ley, the liquor will again become brown, and lofe its caufticity.

On faturating either the firft or laft of the alkaline folutions with an acid, a fimilar precipitate is obtained from each, of a dark coloured matter, almoft infoluble in water, but foluble in cauftic alkali.

Hence it appears, that after raw cotton or linen has been acted upon by alkalies for two or three times, they have no further effect upon it, till the cloth comes in contact with oxygen or pure air, either by immersion in the oxygenated muriatic acid, or by exposure to the atmosphere; and it is on account of the speedy action of the acid, in comparison with that of the atmosphere, that the new mode of bleaching is now generally adopted.

M. Berthollet, and the modern chemists suppose, that the colouring matter of linen is composed principally of carbon and hydrogen; and they conclude, that linen, bleached by the oxymuriatic acid, becomes yellow on this principle, that when the oxymuriatic acid renders linen white, a quantity of oxygen has combined with the colouring particles; but that this oxygen gradually enters into a combination with the hydrogen, and forms water which passes off; that then the carbon becomes predominant, and the linen, in consequence, assumes a yellow colour.

The old chemists, on the principles of Stahl, would say, that a part of the dephlogisticated marine acid, (oxymuriatic acid,) after the cloth had been acted upon by the alkali, absorbed such phlogistic colouring matter from the cloth, as the alkali had no affinity for; and thus became diluted common marine acid, which has a great attraction to cotton or linen, and, if exposed to a moderate heat, will act upon the texture of the cloth, and render it of a yellow colour.

We notice this circumstance in two different points of view, that the bleacher may be aware of the necessity of applying, in either case, a weak ley of pearl-ash, ultimately after the use of the muriatic acid, to prevent this yellowness from occurring; and also that the reader may comprehend the reasoning of Home, and other persons who have written upon the subject of bleaching, previously to Mr. Scheele's discovery.

To recover the pure alkali from the black coloured leys, which have been used in bleaching, and to render them equally proper for the same purpose, has been for a considerable time a material object in the neighbourhood of Manchester, and practised with great success.

To effect this, the black or brown strong leys, which have been left after bucking linen, or cotton yarn, or goods, or saved after wringing them, is put into an oblong flat shallow iron pan, made of plate iron, rivetted together. (See *Plate* IV. *fig.* 4, 5.) Under this pan a fire is made, and the old leys gradually evaporated, till they become of a consistence nearly resembling tar; the matter is then put into casks, and carried to the reverberatory furnace, *Plate* IV. *fig.* 6, 7. where it is laded or poured into the cavity or bed within the furnace; the fire being then made, acts powerfully on the alkaline mass; gradually dries the water left amongst it; then acts on the colouring matter the ley has abstracted from the cloth, which is partly dissipated in a black, offensive smoke, and partly destroyed by combustion; the calcination of the ashes is assisted from time to time, by raking them up with a long iron rod, in order to expose fresh surfaces to the flame; the heat is continued and increased till the inflammable matter amongst the alkali is dissipated, and the ashes brought to a perfect fluid state; they are then let out by an aperture in the side of the furnace, into an old iron pot put into the ground, and when cold, broken into small pieces for use, being frequently in a purer state than when first imported.

Fig. 4. *Plate* IV. is a section of the evaporating pan for the waste leys, where A represents a flat iron pan, of an oblong square form, about six inches deep, and of a size proportionate to the quantity of leys to be evaporated; B, the fire-place; C, the ash-hole: D, the flue in which the fire acts under the pan; E. the chimney for the smoke; F, the brick work.

Fig. 5. *Plate* IV. is a bird's eye view of the same evaporating pan, which is made of plates of beaten iron rivetted together, as shewn in the plan; the fire-place underneath it is marked by dotted lines at B, and the chimney flue at E.

Fig. 6. *Plate* IV. represents a longitudinal section of the reverberatory furnace used in the preparation of ashes, or solid alkaline salts from the old leys after evaporation, to a proper consistence; *a* the brick work; *b*, the ash-hole; *c*, a channel, or passage under the furnace, to admit a free current of air; *d*, the fire-grate; *e*, the fire-place; *f*, the inner part of the furnace; *g*, the bed of fire proof brick, on which the matter is calcined; *h*, the alkaline ley to be calcined; *i*, a door through which the ley is introduced by an iron ladle into the furnace, and through which door the matter, during calcination, is stirred from time to time; *k*, the passage for the smoke, or chimney, which chimney should be from 20 to 30 feet high; *l*, the upper part of the furnace, arched like an oven; *p*, the separation wall between the fire and matter to be fluxed or calcined.

Fig. 7. *Plate* IV. represents the upper plan of the furnace, of which *fig.* 6. is a section; *a*, the outer walls; *b*, the ash-hole and draught-hole; *e*, the iron grate of the fire-place; *g*, the bason in which the leys are calcined; *m*, the door through which fossil coal is thrown into the fire-place; *n*, an iron tube through which the ashes in fusion flow out of the furnace when sufficiently calcined; *o*, an iron pot into which the melted ashes flow, and where they are suffered to cool; *p*, a wall of fire-brick between the fire-place and bason, over which wall the fire passes; *r*, the steps leading down to the ash-hole.

It is necessary to remark, that all the interior part of the reverberatory furnace should be made of Welsh brick, or such as will withstand the action of a strong fire; the whole building should be well bound together by iron bars, or cramps. If so constructed, it will last for several years; and when it then wants repair, the ashes, which will be found accumulated in the interstices of the brick-work, will defray the expence of such repairs.

Having shewn the methods generally used in bleaching linen and cotton, we shall notice a process lately discovered by Mr. W. Higgins of Dublin, for using the sulphuret of lime, as a substitute for pot-ash in bleaching. The sulphuret is prepared in the manner following, viz. sulphur or brimstone in fine powder, four pounds; lime well flaked and sifted, twenty pounds; water sixteen gallons; these are all to be well mixed, and boiled for about half an hour in an iron vessel, stirring them briskly from time to time. Soon after the agitation of boiling is over, the solution of sulphuret of lime clears, and may be drawn off free from the precipitate, which is considerable, and which rests upon the bottom of the boiler. The liquor, in this state, is nearly of the colour of small beer, but not quite so transparent.

Sixteen gallons of water are afterwards to be poured upon the remaining precipitate in the boiler, in order to separate the whole of the sulphuret from it; the matter is then well agitated, and must, when settled, be drawn off, and mixed with the first liquor; to these again thirty-three gallons more of water may be added, which reduce the liquor to a proper standard for steeping the cloth.

Though either lime or sulphur, separately, is very little soluble in water, yet this sulphuret of lime is highly soluble.

This preparation has been applied, in the following manner, to the bleaching of linen in Ireland.

The linen, as it comes from the loom, is charged with the weaver's paste or dressing, to discharge which, the linen must be steeped in water for about 48 hours, and afterwards taken out and well washed; in order to separate the resinous matter inherent in the vegetable fibre, the linen must then be steeped in the cold solution of sulphuret of lime (prepared as above), for about 12 or 18 hours; then taken out and well washed; when dry, it is to be steeped in the oxymuriate of lime, prepared by Mr. Tennant's process, for 12 or 14 hours, and then washed and dried. This process is to be repeated by six alternate immersions in each liquor, which are sufficient to whiten the linen.

Though we must confess, that we have some doubts respecting the application of sulphuret of lime to supersede the use of ashes, in bleaching goods intended to remain perfectly white, yet we think it incumbent upon us to state, that for goods previously bleached for dying, it possesses advantages over those where alkalies have been used, and which has been actually proved above 30 years ago, by the practice of Mr. Peter Henry Ottersen, communicated by him to the late Mr. John Wilson, of Ainsworth, near Manchester. Mr. Wilson's memory deserves every mark of respect from the cotton manufacturers of England, for his numerous improvements in the bleaching, dying, and finishing of cotton goods.

For the use of private families, where the linen is dirtied by perspiration or grease, it will be of great service towards rendering it white, to steep it for some time in a clear liquor, made by mixing one quart of quicklime in ten gallons of water, letting the mixture stand 24 hours, and then using the clear water drawn from the lime. After the linen has been steeped in this liquor, it should be washed as usual, but will require much less soap to be used.

Cotton goods, after bleaching, were formerly dried in the open air, on frames or tenter rails, or on rails in covered buildings, or in large rooms or stoves heated for the purpose, all which modes were attended with great delay and disadvantages.

These difficulties were removed in 1797 by an apparatus, simple in its construction, easily managed, and of singular use in facilitating the process of the bleacher. For this useful invention the public are indebted to John Burns, esq. of Paisley.

By this discovery the bleacher can erect a drying machine, equally useful at all seasons, and in all weathers, at less than one-tenth of the expence of former constructions, for doing business to the same extent. There is no risk of damage from wind or rain, less chance of injury from servants, owing to the simple manner in which the goods are prepared. They receive a fine gloss during the process of drying, the colour is as well preserved as if dried in the open air, and they cannot be injured by the heat.

A contrivance so obviously beneficial and complete, was soon introduced into general practice in the west of Scotland; and so undoubted were the claims of the above gentleman to the originality of invention, that the bleachers in the neighbourhood presented him with a handsome donation of silver plate, suitably inscribed, in testimony of their sense of his merit, and as some reward for communicating his plan to the public.

We are more particular in noticing this circumstance, as some other persons have subsequently taken out a patent for the same principle, with a little variation in the construction of the machine, but which alteration has not been found to answer the purpose as expected. We shall therefore now more particularly describe Mr. Burns's apparatus for drying.

Fig. 1. *Plate* III. A is the boiler or steam vessel; B, the safety valve; C, the hollow leaden pipe which conveys the steam from the boiler to the rollers; D, a brass cock hollowed to receive the pivot of the roller, represented in *fig.* 2. one of which cocks is fixed to the pipe under each roller, and by opening which the steam is admitted into the roller; E represents twelve rollers placed upon the cocks, one of which, next to D, has the cloth upon it in the operation of drying; FFF, the wood frame in which the machinery is placed; GGG, the supporters of the leaden steam pipe, and of the trough HH, which trough is 15 inches broad at top, to receive the water formed by the condensed steam as it drops from the bottom of the rollers, E, and to conduct it to I, a small pipe extending from the trough, H, to the funnel, K, which funnel has its lower pipe reaching to within eight inches of the bottom of the boiler, to prevent the steam from issuing out at its mouth, and which funnel keeps the boiler supplied with water to its proper height, or shews when any is wanted, as the steam would arise through it if water should be wanting in the boiler.

Fig. 2. *Plate* III. shews one of the rollers separate from the frame. It is usually five feet long, one foot in diameter, and made of double tinned sheet iron, and hollow in the middle, for containing the steam; *a* is the lower pivot of the roller, which is an open tube at the end for receiving the steam conveyed through it from the cock. This pivot rises a foot within the roller, at the under part of the roller; at *d* is a small hole for allowing the condensed steam to drop into the trough placed below it as above-mentioned; *b*, the other pivot or axis of the roller, which is fastened to the top bar of the frame by a latch, as represented in *fig.* 1.; *c*, a row of teeth fixed into a small slip of tinned sheet iron, soldered to the roller, and thereby elevated to prevent the teeth from tearing the cloth.

Fig. 3. *Plate* III. a machine about three feet in height, for the purpose of lapping the cloth upon the rollers. A, the box in which the cloth is first laid; B, the farthest wooden roller, over which the cloth passes from A, and from thence under the wooden roller C, to the tin roller D, on which it is lapped by turning it with the handle E; F, the cloth passing under the roller C, to the tin roller D, on which, when it is lapped, it is ready to be carried and placed in the drying machine; G, a weight hung from the projection in the frame at H, over the roller B, to keep the cloth sufficiently tight as it passes from the box A, over that roller to be lapped on the drying roller D.

Fig. 4. *Plate* III. shews another method of lapping the cloth on the tin roller, previous to its being dried. A, a perpendicular frame in the front of which is placed the tin roller B, with a handle for turning it at C; the cloth D extends from the roller B over the wooden roller E, in a frame F to G, where its other end is attached by a wire run across it to some wrapper or linen cloth, fastened to a board H, fixed below the roller B. L L are upright posts fixed to the outer side of the bottom frame KK, having wooden pegs NN in them, on the side nearest the tin roller B. Rails or rods are laid across from these to similar pegs opposite, to prevent the cloth touching the ground when it is adjusting in the beginning of the operation, and the number of these posts necessary, therefore, are in proportion to the length of the cloth.

At the commencement of lapping the cloth on the tin roller B, the frame F, moveable on small rollers II, running in grooves on the frame KK, is drawn so far back, that when the cloth is fastened to the wrapper G, one half of the piece reaches to the roller F, the other half passed over that roller, reaches to the tin roller B, to which it is then to be fastened. On turning the handle C, the cloth is gradually lapped round

the roller B, the moveable frame F being drawn forward by the cloth; for as the cloth is lapped on the roller B, the frame F is drawn towards it betwixt the uprights LL, and by means of a projecting wood forming an inclined plane fixed at M, on each side, near the top of the frame F, the rails O are raised off the pegs NN, and carried forward on the part M of the frame F, without impeding its progress to the tin roller B, till the wrapper G, to which the cloth is fastened, passes over the roller, and the wire at G, which attaches it to the cloth, is withdrawn, leaving the whole of the cloth to be dried on the tin roller B, which roller is then taken out and placed in the drying frame.

To ascertain the strength of the oxygenated muriatic acid used by the bleachers in France, Monf. Deferoizilles made use of a solution of indigo in the vitriolic acid, for which purpose he takes one part of finely pulverized Guatimala indigo, and eight parts of concentrated vitriolic acid, which mixture should be put in a glass vessel, and kept of a gentle heat by standing near the fire or in warm water all night, and repeatedly stirred with a glass rod or tube. When the solution is complete, it is diluted with a thousand parts of water. One measure of this solution is put into a graduated tube of glass, and oxygenated liquor is added, until the colour of the indigo is completely destroyed, and the strength of the oxygenated liquor is ascertained by its power in discharging the colour.

Mr. Rose has recommended a method which is better adapted for general use; which is, "to have small measures properly proportioned to each other, and when the liquid is strong, to prevent waste of the indigo liquor prepared as above, and a tedious repetition of measures, let a small measure of the liquor to be tried be put into a measure containing 24 of the same measures of water (it then becomes diluted to a twenty-fifth part); to a measure of this diluted liquor add as many measures of the blue test as it will discharge, which multiplied by 25, gives its whole strength. It will be proper to have a measure of five for the sake of dispatch, in adding the blue test liquor. It is necessary that the experimenter should sit low enough to view his measures horizontally, in order that they may not be overfilled, otherwise he may be deceived.

Great care should be taken in the choice of the indigo and the vitriolic acid employed, for unless the indigo is of the Guatimala kind, or best East India, and the vitriolic acid highly concentrated and pure, the colour produced will be a greenish brown, instead of a bright blue.

Mr. Chaptal has employed the oxygenated muriatic acid to the purpose of bleaching paper, both by applying it to the rags before worked down, and to the pulp or paste; he also restored the white to prints discoloured by time, by immersing them in the oxygenated muriatic acid liquor, or exposing them to the action of its vapour. And several patents have been granted in this kingdom for bleaching pulp or paper, amongst which Messrs. Clement and George Taylor, of Maidstone, in Kent, have obtained one for bleaching the pulp, by inclosing it with a liquor of oxygenated muriate of pot-ash, in a vessel resembling a churn, eight feet diameter at the great end, three feet four inches diameter at the little end, and two feet ten inches in the clear. This vessel revolves upon an axis at each end, and the pulp, by this motion, and projecting parts within the vessel, is constantly exposing fresh surfaces to the liquor, till the whole pulp is sufficiently whitened.

Mr. Bigg, of Iping, in Sussex, has since obtained a patent for bleaching paper, and restoring to whiteness damaged or mildewed paper, by exposing in close wooden vessels paper, in quantities of six or eight sheets together, on wooden frames placed at small distances from each other, to the action of oxygenated muriatic gas, and after the paper is taken out, pressed, and dried, previous to its being sized, wetting it in a solution of alum water.

Another method he proposes, is by wetting and soaking the paper in oxygenated muriatic acid liquor, till it is properly bleached; after which it should be well pressed and dried, and wet out in the alum water, as in the other process.

A patent has likewise been granted to Mr. Elias Carpenter, of Bermondsey, London, for a method of bleaching paper in the water leaf or sheet, and sizing it without drying; he uses for this purpose a stout deal box or case, which must be carefully closed, and capable of confining water or steam within this. The paper to be bleached is to be hung on strips of glass, about 15 inches long, placed in grooves within the box, about four sheets on each strip; the paper is taken for this purpose when pressed in the packs in its wet state, and when the box is filled and closed, it is exposed to the action of oxygenated muriatic gas for eight or ten hours, and when sufficiently bleached, sized with a preparation made from one hundred weight of pieces of skins boiled in water and strained, then fourteen pounds of alum, seven pounds of white vitriol, and one pound of gum arabic added; these ingredients will make size enough for about 50 reams of foolscap paper; the paper when sized and pressed, is finished in the usual way. To prevent the noxious qualities of the gas to the workmen, he directs a solution of pot-ash in water to be placed at the bottom of the bleaching box, to absorb the elastic vapours which would otherwise affect them on opening the box.

Mr. Tennant of Glasgow, subsequent to the patent granted him for his bleaching liquid, has obtained a patent for preparing the oxygenated muriate of lime in a dry form, by which means bleachers may be cheaply and conveniently supplied with it by him, and save much of the trouble, expence, and hazard which attend the preparation of the former bleaching liquor.

To bleach silk from its natural gummy state, whether in skain or manufactured, it should be put into a thin linen bag, and thrown into a vessel of boiling water in which good white soap has been dissolved; the silk should boil two or three hours in this liquor, and the bag of silk frequently pressed with a stick, and turned, so that the gummy matter may separate from it, and rise to the surface of the liquor, from whence it should be skimmed off, and thrown away; the bag should then be taken out, and if it contains silk goods, they should be well washed in clean cold water, to prepare them for printing or dyeing; but if the bag contains silk in the skain, after it has been well washed in clean water, beaten, and slightly wrung, it may be put the second time into the copper vessel, filled with cold water mixed with soap, and a little indigo blue, if you wish it tinged a little of the blueish hue.

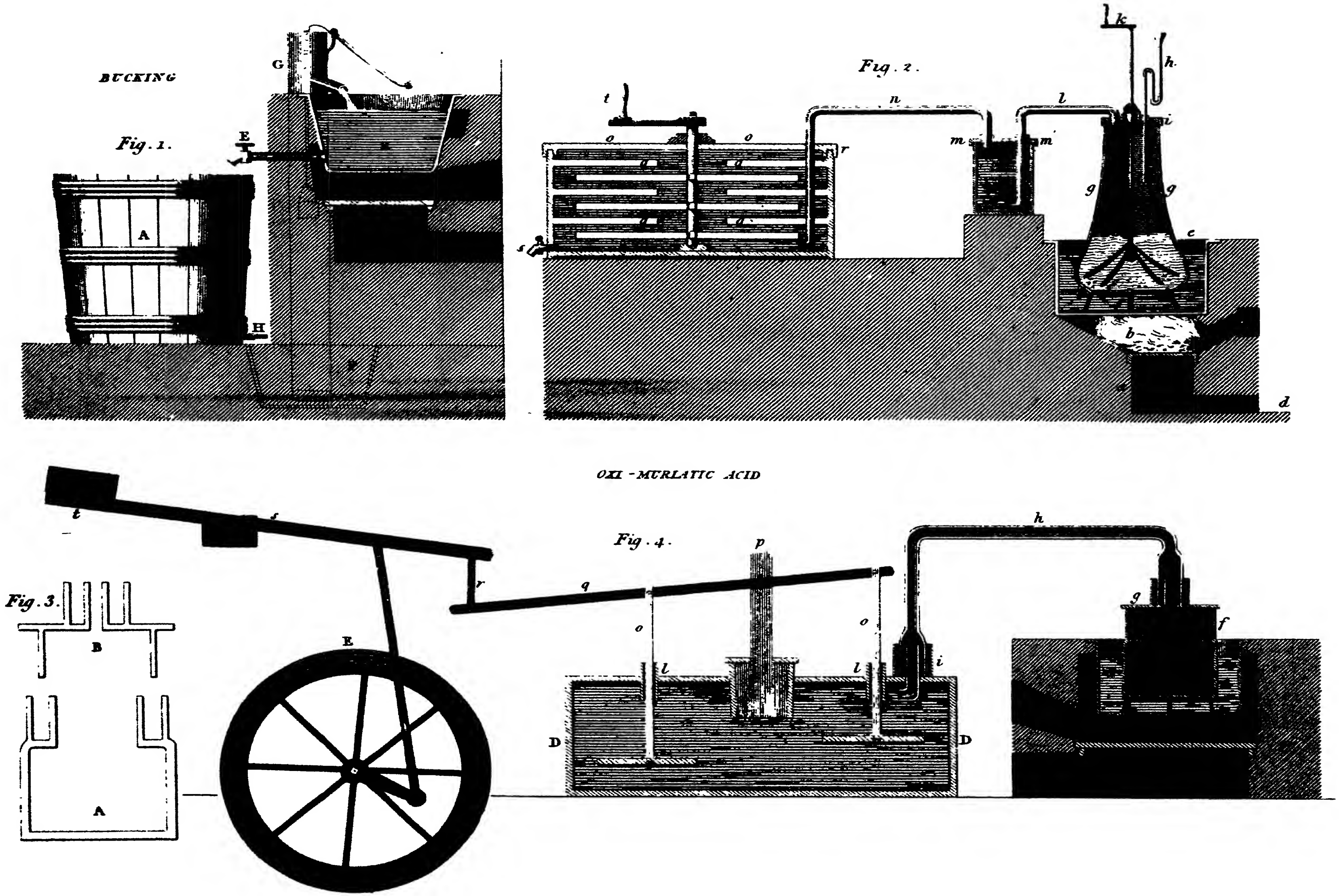
The silk, when taken out of the second water, should be wrung hard with a wooden peg, to press out all the liquor; then shaked, to separate the threads; then suspended on poles, in a close room or stove where sulphur is burnt, which improves the whiteness of the silk.

Woollen cloths or stuffs may be bleached and made white by soap and water; by the vapour of sulphur; or by chalk, indigo, and sulphuric vapour. In the first case, after the stuffs have been cleaned at the fulling mill, they are again worked in warmish soap and water, to render them whiter, and afterwards washed in clear water and dried; in this state they are fit for dyeing any light colours.

To destroy or remove the reddish hue arising from boiling printed cottons in madder decoctions, which prevents the

printed colours appearing to advantage, the goods are ufually boiled for fome time in bran and water, and then expofed to the air, by laying them on the grafs, and throwing upon them clear water from time to time. Mr. Grimfhaw, in the year 1796, obtained a patent for clearing printed goods coming from the madder copper, by ufing the grains after brewing malt liquors, inftead of bran; the plan he recommends is, that the grains fhould be previoufly four, and that three or four bufhels thereof, more or lefs, according to the colour of the cloth, fhould be put into a copper of hot water, containing 200 gallons or upwards, and four or five pieces of the printed cotton goods then immerfed therein, and worked over a winch backwards and forwards, for ten or fifteen minutes; the pieces are then taken out of the copper, and well wafhed in clear water, and laid ftraight upon the ground for two or three days, till the parts which fhould be white become clear. The fame liquor, with the addition of a few grains, will ferve to clear other printed goods, till the whole number wanted to be cleared have been completed; a fufficient quantity of clear water being added to replenifh what has been abforbed by the goods, or evaporated in boiling. After either of the operations above-mentioned, the immerfion of the printed goods in dilute oxygenated acid, will anfwer the purpofe of the expofure to the air.

BLEACHING



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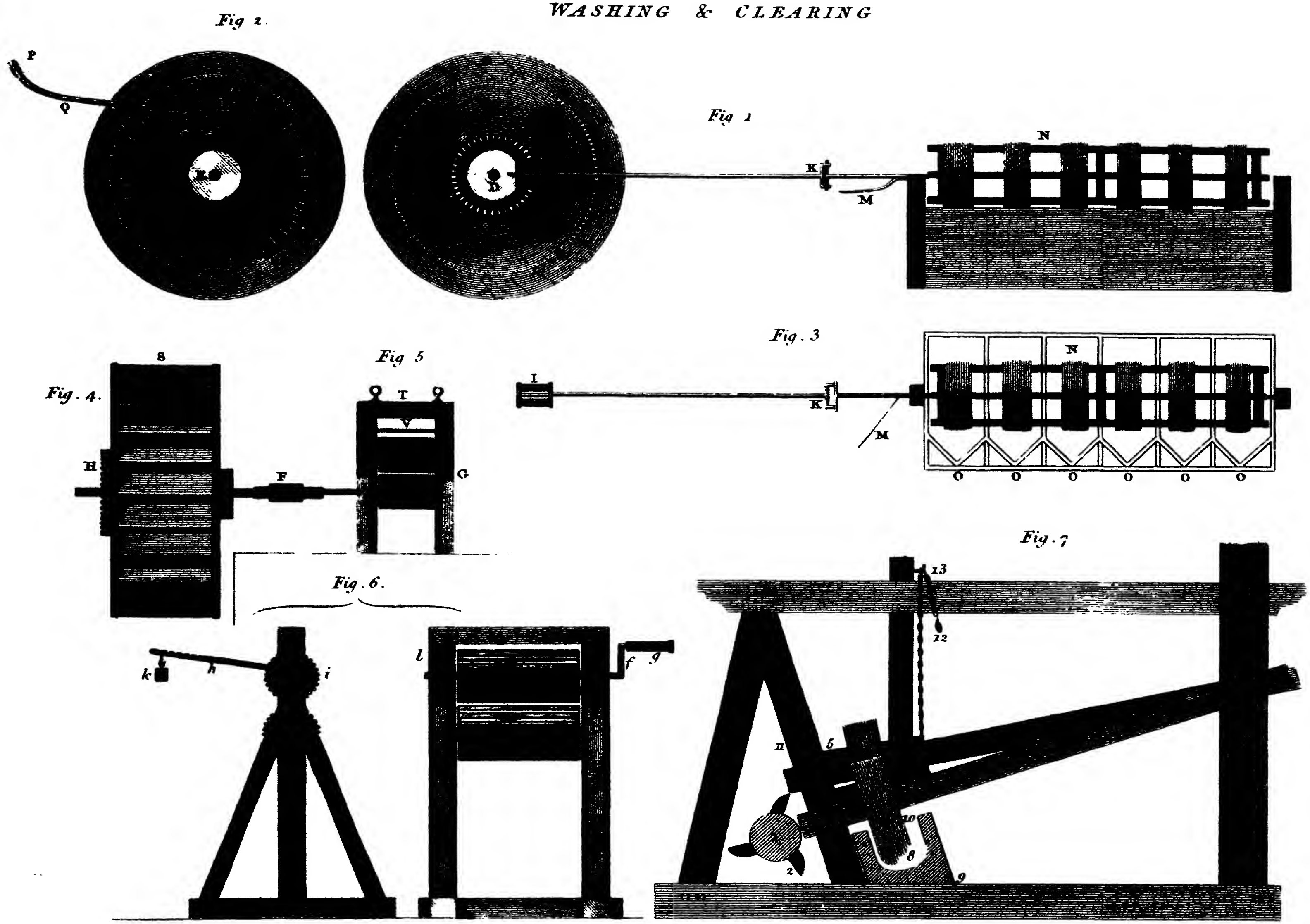
BLEACHING.

WASHING & CLEARING



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BLEACHING.

DRYING.

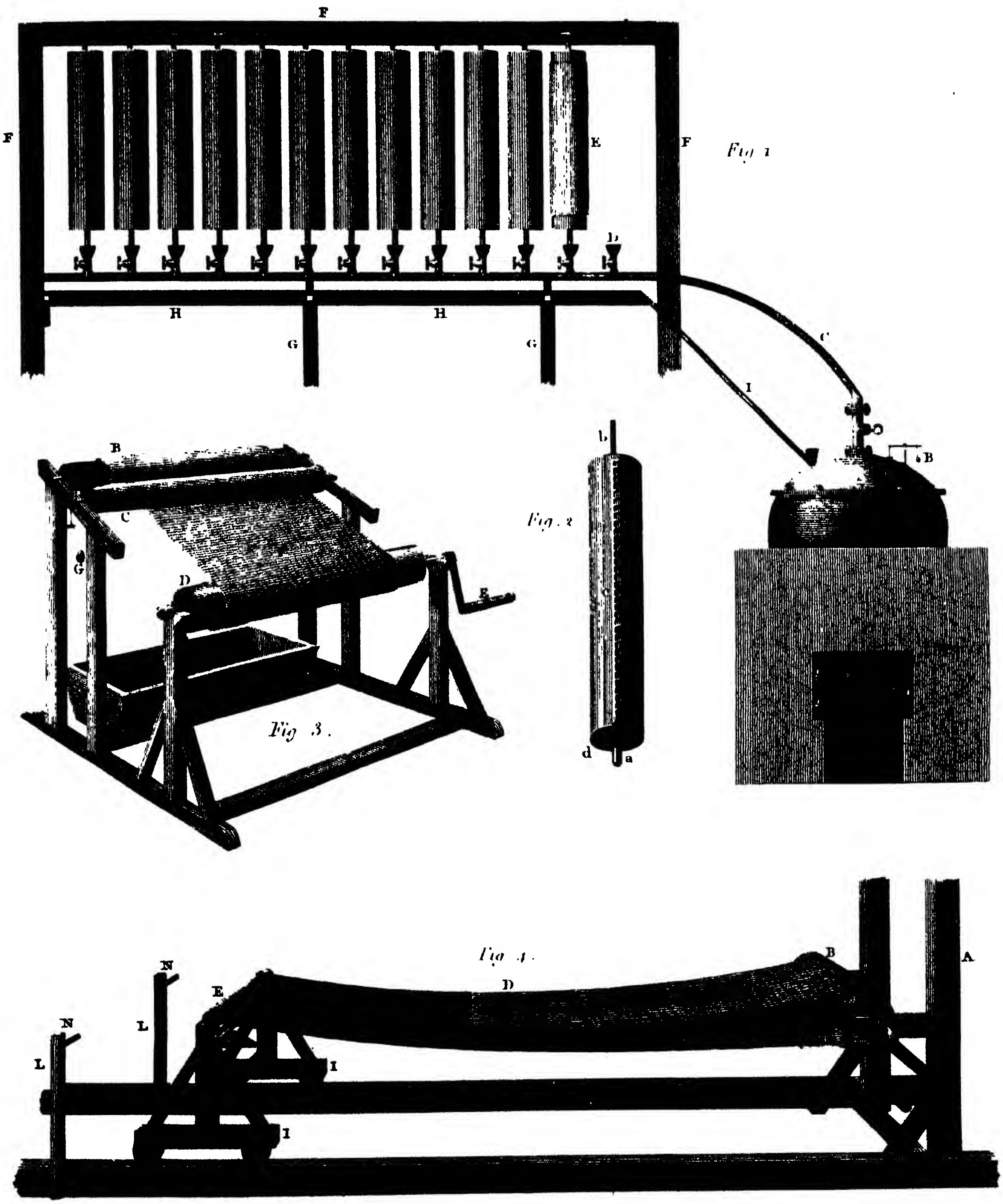

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Fig. 1.

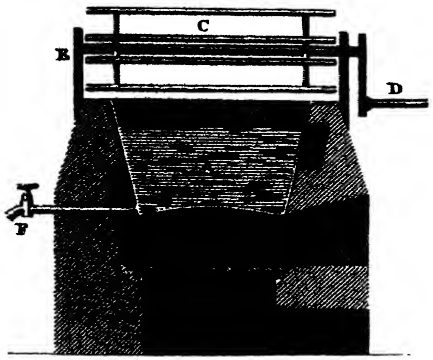


Fig. 2.

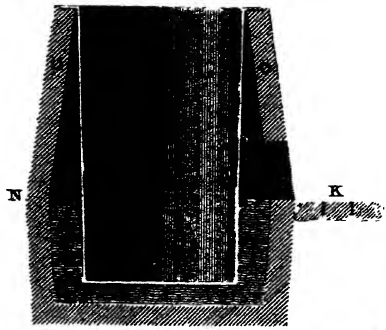


Fig. 3

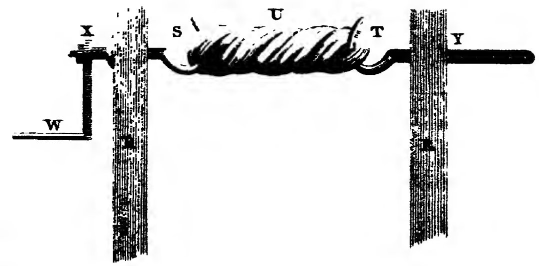
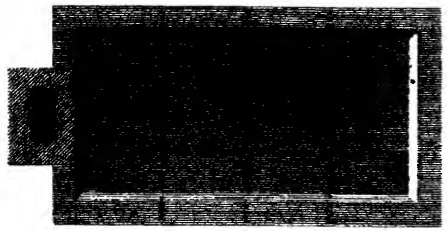


Fig. 5.



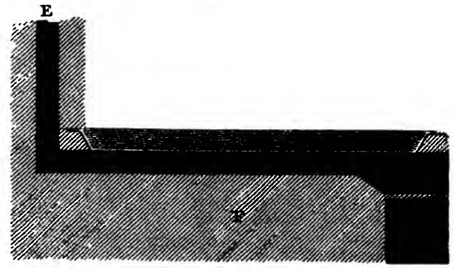


Fig. 4.

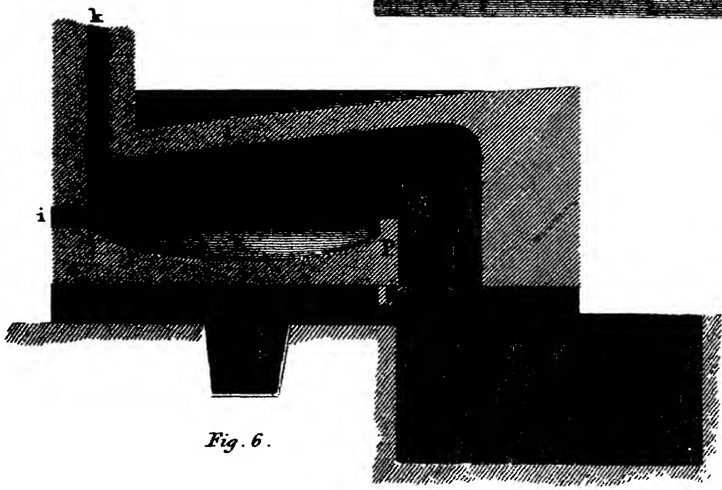


Fig. 6.

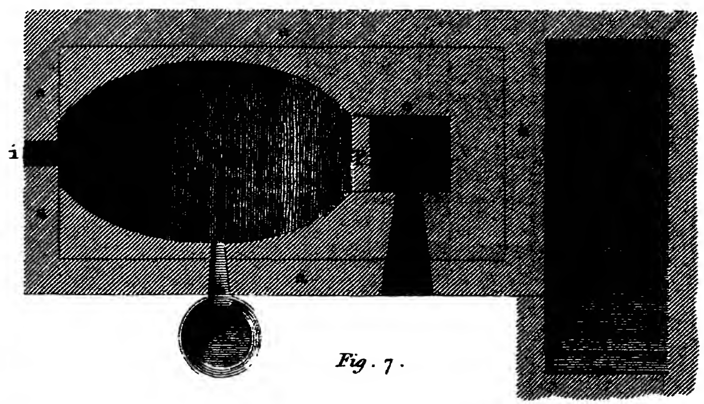


Fig. 7.

Drawn by C. Varley

Published as the Act directs, March 1st 1805, by Longman Hurst Rees & Orme Paternoster Row

Engraved by Wilson Lowry.

Blowing of Glass

Blowing of Glass, one of the methods of forming the divers kinds of work, in the glaſs manufacture. It is performed by dipping the end of an iron ponteglio, or blow-pipe, in the melted glaſs, and blowing through it with the mouth, according to the circumſtances of the glaſs to be blown.

Blowing *of tin*, a term uſed by the Corniſh miners for the fuſion or reduction of tin-ore to the metallic ſtate, after having been roaſted to get rid of the ſulphur and arſenic.

Blowing *Machine*, is uſed in metallurgical operations on a great ſcale, for the purpoſe of exciting combuſtion in furnaces appropriated for the ſmelting and reducing of ores.

The hiſtory and improvement of machinery of this nature have kept pace with the other branches of our national manufacture, and, in many inſtances, may be juſtly ſaid to have gone beyond them.

In the ſmelting of lead and tin ores, the ſize and powers of the blowing machine have been leſs a ſubject of alteration and improvement, than thoſe uſed at furnaces and works where iron ore is ſmelted.

The natural fuſibility and eaſy volatilization of the former metals, in temperatures beyond a bright red heat, have preſcribed the ſize of the furnace, the meaſure of the blaſt, and the nature of the fuel.

In the manufacture of copper, air-furnaces are generally uſed, except where precipitated oxyd of copper is revived in ſmall blaſt-furnaces, reſembling thoſe called cupolas, uſed at iron founderies.

The conſtruction of a lead ſmelting machine, or what is commonly called a "Lead Mill," is extremely ſimple. A water wheel is erected in the middle of a ſquare building. To the ſhaft of this wheel are attached four ſmall wheels of caſt iron, about 18 inches diameter. Four pairs of bellows, two pairs on each ſide of the ſhaft, are placed at equal diſtances, and ſupported upon a ſtrong framing of wood. As the water wheel ſhaft revolves, the ſmall wheels are carried round, and alternately, or two and two together, depreſs the extremity of a lever attached by an iron chain to an equipoiſed beam, the deſcent of this lever elevates the oppoſite end of the beam, to which is alſo attached, by means of another iron chain, the upper or moveable ſurface of the bellows. The blaſt produced in this way is in general ſo far, much inferior in point of either quantity or denſity to what is found neceſſary at iron furnaces. The bellows in common meaſure 10 feet in length, and 5 or 6 feet acroſs the breach, moving about 30 ſtrokes per minute.

In the manufacture of iron it has always been, particularly ſince the introduction of pit coal, the unceaſing object of the iron-maker to improve his blowing apparatus; for uniformly he has found, that in proportion as he can raiſe air, and make it enter the furnace, ſo will his weekly quantity of metal be increaſed.

In the early hiſtory of this intereſting manufacture, when charcoal of wood was the matter of fuel made uſe of, the affinities betwixt the latter and the ore were eſtabliſhed with more facility. Small furnaces, called bloomeries, were ſufficiently large, and deemed of profitable capacity, if they produced a bloom or two of iron per day, of 90 to 120lbs. each.

Hand bellows, and what were called fuel blaſts, were ſufficiently large for the minor operations. After the general introduction of the refinery furnaces, and the diviſion of the manufacture into the making of pig iron, and the refining of this into bar or malleable iron, the advantages of a powerful blaſt were immediately perceived. Water wheels, working two pairs or more of leather bellows, were found to produce powerful effects, and, in conſequence, almoſt every ſituation that preſented a command of materials and a waterfall, became the ſcite of an iron-mill.

The ſimple mode of blowing furnaces by means of a trompe, was at the ſame time introduced; but in general it was found, that much greater advantage could be derived from the deſcent of water upon a wheel, either as to denſity or quantity, than by means of the beſt conſtructed trompe.

The uſe of water wheels and leather bellows continued general throughout the iron buſineſs, until the principles and mechaniſm of the ſteam engine were eſtabliſhed upon unerring grounds. This wonderful invention was ſoon applied with the happieſt effect in many ſituations rich with mineral treaſures, but to which nature had denied the advantage of water ſufficient to turn machinery. Cylinders, compoſed of wood, firmly jointed and hooped, were firſt introduced as a ſubſtitute for leather bellows: theſe were ſoon after replaced by bored cylinders of caſt iron; and with

with this great discovery and application of the art of casting, the blowing machine assumed a general and well-proportioned form.

This took place nearly 40 years ago, and continued with a few temporary deviations until the introduction of Bolton and Watt's highly improved engine. The following may serve for an outline of the old blowing steam engine.

A steam cylinder, working with atmospheric pressure from 3 to 7 lbs. upon every square inch of the area of the piston. The diameter of the cylinder for one furnace varied from 25 to 36 inches, and for two furnaces from 36 to 50 inches. Upon the opposite of the main or working beam, sometimes at equal, and sometimes at unequal distances from the centre, was placed the air-pump or blowing cylinder. This was, in common, equal to four or five times the area of the former; and, with the small working power of the steam cylinder, seldom condensed the air beyond 1½ to 1¾ lbs. per square inch. The air-pump was commonly constructed open below, as may be seen in *Plate* II. *fig.* 1. (*Chemistry*). The plan was sometimes deviated from, and the cylinder inverted. The blowing piston was loaded with weights, and the air expressed by its descent. In this mode of working, the act of the steam piston, descending in vacuum, raised the air-pump piston loaded with weights. Upon the return of the stroke, or while the steam piston ascended in the cylinder, this piston loaded with weights sunk the whole length of the stroke, and by means of this loading, proportioned to the powers of the engine, forced the air either into the regulator or the furnace.

Above, or parallel to the air-pump, was placed the regulating cylinder, as may be seen in the plate above mentioned. This had a valve of communication, which opened every stroke the engine made, and admitted the whole discharge of air. The piston of the cylinder, frequently called the fly piston, was loaded with weights, and kept constantly vibrating; so that when any deficiency of pressure arose from the remitting action of the air-pump piston, the blast was comparatively equalized by the pressure of the fly piston upon the included air. The size of this cylinder was generally in the proportion of 9 to 6 of the air-pump.

The chief objections to this mode of blowing, even when in universal use, were founded upon the great inequality of the blast, and a very considerable waste of air that took place at the *snort*, or safety valve, to prevent the fly piston being blown entirely out of the cylinder. The snort was an opening made in the top of the air-pump cylinder, on which rested a heavy iron valve, faced with leather stuffed with wool; this was, by means of an upright iron rod, attached to a lever, which run across the top of the regulating cylinder. As soon as the fly piston arose to a certain height, a block of wood, or other contrivance, lifted the one end of the lever, and along with it the valve, to a certain height, and permitted a quantity of the densest air to escape, sufficient to insure the safety of the piston. Notwithstanding these precautions, many accidents and stops ensued; the breaking of a pin, or the loosing of a key, frequently ejected the piston from its cylinder, though loaded with several tons of weight.

Some iron masters, more ingenious than others, contrived to take the spare or waste air from the snort, to receive it in an inverted chest above water, and blow to its extent smithy and finery fires. Endeavours of this kind to husband and economise air, raised and condensed at a great expence, were sufficient proofs that a method was still wanting to complete the blowing machine, to render its motions steady and uniform, and to equalize the density of the blast throughout the whole stroke.

This was completely accomplished by inverting large chests, or cylinders, in cisterns of wood, stone, or iron. The space betwixt the inner and outer cisterns was constructed of sufficient capacity to oppose to the expansive force of the blast a column of water of equal or superior resistance.

This invention was called the water blast, water pressure, water regulator, &c. The dimensions differed materially from from each other; this circumstance being much regulated by conveniency, opinion, and the size of the engine.

Plate XIV. *fig.* 1. (*Chemistry*) represents a ground plan of a very capacious water regulator, sunk in the ground, and built of stone and bricks.

A, the inverted chest made of plates of cast iron, 40 feet long, 12 feet wide, and 12 feet high. The square superficies of this chest is equal to 480 feet, and its cubical contents are 5760 feet. Its weight will amount to nearly 30 tons.

B, the opening to which the air-pipe is attached; 2 feet diameter.

CCCC, open space betwixt the inverted chest and stone cistern, for the column of water to ascend; 3½ feet wide.

DDDD, stone or brick-work, of which the great cistern is built. This work requires to be well jointed, as the motion of the water has a great tendency to open the spaces betwixt the stones. This cistern is 47 feet feet long, 19 feet broad, and 14 feet high; its cubical measurement amounting to 12,500 feet, and capable of containing 93,500 gallons wine measure.

eeee, an opening of one foot in breadth left in the middle of the building. This is compactly filled with well trod clay, called puddling, and prevents the escape or circulation of water through the building. Beyond this the common building extends to a sufficient thickness to give general security to the whole.

Fig. 2. is a cross section of the water regulator at B, *fig.* 1. The letters in this view correspond with those in the plan.

F, the blast pipe from the cylinder entering the chest, and branching to the two blast furnaces.

GG, large hewn stones, on which the chest is supported, about two feet from the bottom of the cistern, at intervals of six feet from each other.

H, loading of hewn stone, which for this cistern requires to be equal in all to 90 tons. If the chest weighs 30, then 60 tons of loading will be requisite. This is supposing that the power of the blowing machine is calculated to press equal to 3 lbs. upon every square inch, which many of them are constructed to perform.

To comprehend distinctly in what manner the water regulator performs its functions, and upon the supposition that the compressing power of the engine is equal to 3 lbs. upon every square inch, we shall suppose the engine at rest, and water introduced into the regulator, till it rise to the level of the dotted line *h*, 5 feet from the lower edge of the chest, and 7 feet in total depth of water. As soon as the engine is set to work, the compression of the air immediately sets the water in motion; every stroke making the water rise in the space CC, and proportionally falling towards GG, in the interior of the chest.

When the inverted chest becomes filled with air, and the condensation has reached the maximum of the power of the blowing machine, the water will be found elevated 3½ feet to *i*, and the gauge will exhibit a depression in the interior of the chest, from *h* to *k*, 3½ feet, making in all 7 feet from *k* to *i*.

At every turn of the engine stroke, the water maintained at *i* falls a few inches, and elevates itself above *k* in the in-

terior of the cheſt, a ſimilar height. This deſcription takes it for granted, that the ſpaces CC are equal to the area of the inverted cheſt; ſo that every inch of water forced out of the cheſt adds exactly one inch to the height of the column.

A blowing machine, capable of blowing to purpoſe two blaſt furnaces, ought to have the inverted cheſt of the regulator equal to three or four hundred ſquare feet of area. There cannot ariſe any error from having this large enough; the want of ſpace and capacity frequently proves a real detriment.

In calculating the proportions and dimenſions of water regulators in general, the principle is, to allow the ſpace around the inverted cheſt equal in point of ſuperficial meaſurement to the area of the interior of the cheſt, that the deſcending column of water may diſplace no more in the perpendicular aſcent, than it is itſelf abſolutely depreſſed.

If the area or ſpace in which the water riſes and falls, is only equal to half the area of the inverted cheſt, then for every foot of water which is depreſſed in the bottom of the cheſt, a column of two feet will be raiſed and maintained on the outſide. On the contrary, if the outſide ſpace for water be equal to twice the area, then every foot of water depreſſed in the cheſt will only elevate the external column ſix inches.

It will appear evident from theſe general facts, that a conſiderable latitude may at any time be aſſumed in conſtructing the water regulator, particularly in old eſtabliſhed works, where local circumſtances and conveniency confine its ſituation to one ſpot.

Where it is not inconvenient to uſe a high perpendicular column of water, the inverted cheſt may be increaſed one half, double, or even triple the ſuperficial meaſurement of the outſide ſpace; ſo that if the power of the blowing machine is equal to 3 lbs upon the ſquare inch, the water in the cheſt will be depreſſed $3\frac{1}{2}$ feet nearly, and raiſed in the perpendicular column 5 feet 3 inches in the firſt, 7 feet in the ſecond, and $10\frac{1}{2}$ feet in the laſt caſe. This plan to ſuit former eſtabliſhments may be adopted with conſiderable modifications, always keeping in mind, that every foot of area gained upon the ſurface of the water is a material acquiſition to the equalizing powers of the regulator.

One imperfection attends this want of equilibrium on the two ſpaces for the action and re-action of the water.—Whatever ſpace the waters would fall, at the return of the ſtroke, ſuppoſing the inſide and outſide columns exactly balanced, would in this caſe be increaſed one half, double, or triple.

Again, where ſituation does not admit of the perpendicular column being raiſed beyond, or not even to the extent of the depreſſion, that takes place within the inverted cheſt, and where an additional ſpace cannot be procured for an increaſe of its diameter, an inverted cheſt of much leſs height than common may be uſed, loaded with a material of great weight, ſuch as iron. The water in that caſe would diſtribute itſelf over the ſurface of the cheſt, inſtead of riſing in perpendicular height.

One ſerious objection, however, is made to cheſts or cylinders, where the eduction pipe approaches within a ſhort ſpace of the ſurface of the water; namely, water riſing in the pipes, and being conveyed along with the air into the furnace. This may take place in two ways; by an inſenſible and uniform diſcharge of water into the furnace, making the blaſt at the tuyere viſible, like the reſpiration of the human body in a froſty day; or in quantity, threatening utter deſtruction to the furnace and buildings. The former is occaſioned by the air from the eduction pipe, at the commencement of the ſtroke, impinging violently upon the ſurface of the water, and raiſing a portion of it in the ſtate of ſpray. This is ſpeedily diſſolved or entangled in the maſs of condenſed air before the return of the next ſtroke, and becomes expreſſed along with the blaſt into the furnace. The other hazardous conſequence is occaſioned chiefly by undulation in the column of water, when the blowing machine is, by derangement or accident, working under its proper power or number of ſtrokes. In theſe caſes, when the pauſe at the end of the ſtroke is prolonged, an exhauſtion ſometimes takes place in the air-pipes, the water riſes and is carried in a ſtream through the blow-pipe into the furnace

The ſame caſualties may more readily occur, if the ſurface of the water is upon a level, or nearly ſo, with the tuyere.

In judicious erections this is moſt carefully avoided; the ſurface of water in the inverted cheſt or cylinder is kept at leaſt 8, 9, and 10 feet under the level of the tuyere even at the laſt period of return, when the water has riſen to its greateſt height within.

This very proper precaution enſures an advantage of much importance. A large ſpace is obtained betwixt the top of the cheſt and the depreſſed ſurface of the water; this becomes a ſpacious reſervoir for the condenſed air, and, by generating a conſiderable portion of elaſticity, prevents any violent perturbation upon the water at any period of the ſtroke. The increaſed diſtance betwixt the ſurface of the water, and the pipe which conducts the air from the cylinder, has a complete tendency to prevent the elevation of the aqueous particles, and always enſures a quantity of air comparatively free from moiſture.

Upon the principles formerly noticed, it is poſſible to conſtruct a blowing apparatus of this nature, wherein there could be little or no viſible motion in the perpendicular column of water even with the ſame engine.

Let us ſuppoſe a machine of this nature at work, with an accurately balanced column of water, the fall of which, at the return of the ſtroke, was equal to 12 inches. It is evident, that if the outſide ſpace was enlarged ſo much over its ſurface as to contain this foot of water, without adding any perceptible height to the column; that included within the cheſt would, at the return of the ſtroke, being fed from a more capacious limb, riſe a foot, without any ſenſible diminution taking place in the perpendicular height of the external fluid. It is equally obvious, in this as in every caſe with water regulators, that the riſe and fall of the inſide column of water will remain the ſame, under every modification and form, while the pace and powers of the engine remain the ſame.

The application of water regulators to blowing machines was ſoon followed by an attempt to further improvement, by the introduction of the air-vault; the principle of which was to form a receiver of ſuch capacity, that the elaſticity or ſpring of the condenſed air would be ſufficient to expreſs and equalize the blaſt during the return of the ſtroke.

To effect this, an immenſe magazine was requiſite; to erect which of any metallic ſubſtance would have been ruinouſly expenſive, and, if conſtructed of wood, inſufficient for retaining the air. It became therefore requiſite to try the experiment upon building, or by excavation from the ſolid rock. In both theſe ways has the air-vault been tried, and found to produce an excellent effect, as to equalizing the denſity of the blaſt; but it has been conceived with ſuch indifferent conſequences as to quantity, that the plan is for the preſent given up.

Air-vaults were conſtructed both at the Clyde and Muirkirk iron works in Scotland, and a conſtant current of air produced; but nearly one half the quantity lifted by the air-pump eſcaped through the walls and arches of the building. This was at any time made viſible by rubbing ſoapy water upon the external walls.

At Devon iron works in Scotland, an air-vault was excavated from the ſolid rock, 72 feet long, 14 feet wide, and 13 feet high; equal to 13,000 feet of cubical meaſurement. This immenſe excavation was made comparatively air-tight, by cauking the ſeams and fiſſures of the rock, plaſtering and then covering the whole with alternate layers of pitch and cloſe wove paper.

This was the moſt perfect experiment ever tried upon the air-vault; and if an opinion is to be formed of the perfection of the apparatus by the quantity of iron at one time manufactured, a very trifling portion of air indeed muſt have been loſt.

It has been frequently noticed in Scotland, that at works where the materials were in any degree ſimilar, 3000 to 3500 cubical feet of air per minute will, in the courſe of a week, produce from 30 to 35 tons of pig iron, whatever may be the denſity at which it is thrown into the furnace.

The Devon furnace at one time averaged 33 tons weekly for 9 months running, and conſumed of air, per data furniſhed by Mr. Roebuck in his paper publiſhed in Nicholſon's Journal, vol. iv. nearly 3400 cubical feet per minute, under a preſſure of $2\frac{3}{4}$ lbs. per ſquare inch. Notwithſtanding this powerful demonſtration, ſtrong prejudices were entertained to its diſadvantage; and many believed, that had any other mode of regulator been attached to the blowing machine, abundance of air would have been obtained to have blown two furnaces equally well. That this idea was incorrect, may be eaſily gathered by calculation from the area of the air-pump, the length of the working ſtroke, and the number of ſtrokes per minute, all of which are particularly ſtated by Mr. Roebuck.

For the general conſtruction of an air-vault formed by building, ſee *Plate* XV. (*Chemiſtry.*)

Fig. 1. is a ſection of the vault conſtructed under the bridge-houſe, or place where the materials are proportioned, previouſly to their being thrown into the furnace. One half a blaſt furnace outline, is ſeen as connected in point of ſituation and blaſt to the air magazine.

A, the termination of the blaſt pipes that convey the air from the blowing cylinder into the receiver, 3 feet diameter; the length depends upon the contiguity of the engine to the vault.

B B B B, four vaults, 13 feet wide each, 25 feet deep, and 10, 11, 12, and 13 feet high to the ſpringing of the arches; total height to the crown of the arches, $16\frac{1}{2}$, $17\frac{1}{2}$, $18\frac{1}{2}$, and $19\frac{1}{2}$ feet. Theſe cells communicate with each other by arched openings in the croſs-walls, which may be diſtinctly ſeen in the ground plan at L.

C C, the eduction pipes that carry the air to the furnace; 18 inches diameter.

D, end view of the range of laying pipes at the tuyere of the furnace. The dotted lines betwixt D and C are meant to repreſent the horizontal range of the pipes.

E, part of the outline of a blaſt furnace to ſhew its proper ſituation to the air vault.

F F F F, floor of the reſpective vaults, compoſed of a mixture of two parts of boring duſt, two of fine riddled lime, and one part of fine roaſted iron ſtone, mixed up into plaſter with water containing a conſiderable portion of ſalt.

G G, end walls of bricks or ſtone, four feet thick.

H H H, lining of brick-work, built in the moſt accurate manner, with fine riddled mortar, and run every ſecond or third courſe with mortar made thin and very liquid. Theſe walls are two feet and a half in thickneſs, are carefully plaſtered, and afterwards covered with ſeveral layers of ſtrong paper and pitch, to prevent the eſcape of air. The roofs of the vaults are finiſhed in the ſame manner.

I, door arch into the vaults; entrance obtained by means of a ladder or wooden ſtairs ſuſpended within.

K, ſpace above the arches, filled with rubbiſh, to prevent any ſpring, and to raiſe the floor to the level of the furnace top.

L, the range of the floor, or acclivity to the furnace mouth.

Fig. 2. is a ground plan of the bridge-houſe containing the air-vaults, and exhibits one half the ground plan of the furnace through the centre of the tuyere arches.

B B B B, correſponding to the ſame letters in the elevation.

C C, pipes for taking off the blaſt into the furnace.

D, correſponding to the ſame letter in the ſection.

E, main pillar of the furnace, ſame as E in the ſection.

G G G G, and H H H, correſpond with the ſame letters in the elevation.

I, ſquare for receiving the furnace hearth.

K, part of the ground view of the hearth, and the approaching blaſt pipes.

L L L, openings of the croſs arches, which communicate the vaults with each other.

The cubical contents of a vault, conſtructed according to theſe dimenſions, will amount to 20,000 feet.

In general, it may be remarked upon the conſtruction of the blowing machine, that ſince the period of the introduction of Mr. Watt's engine, the air-pump, or blowing cylinder, has been conſtructed ſo as to diſcharge a cylinder full of air every aſcent and deſcent of the piſton. This, inſtead of travelling 4 to 5 feet per ſtroke, more generally moves 8 feet; and the number of cylinders per minute are ſeldom under 24.

Formerly, in the common atmoſpheric engine, the movement of the piſton from top to bottom, and back again, produced only one cylinder full of air from the air-pump, and the number of cylinders diſcharged per minute ſeldom exceeded 16. A ſteam cylinder of 40 to 44 inches diameter, and an air-pump of 6 feet diameter, the piſton moving about 5 feet per ſtroke, were deemed ſufficient in the conſtruction of a blowing machine for two blaſt furnaces. The quantity of air pumped up and thrown into the furnaces by ſuch an engine ſeldom exceeded 3000 cubical feet per minute. This, and even a larger quantity, is now thrown into one furnace, and the produce by ſuch means increaſed from 15 to 35 tons weekly.

The firſt ſet of tables following are calculated to ſhew the quantity of air that would be diſcharged by blowing cylinders of various diameters, the length and number of the ſtrokes being given.

The ſecond ſet, to ſhew what diameter of blowing cylinder is requiſite, with a given ſteam power, to raiſe the air to a certain denſity per ſquare inch. See Engine, Water Regulator, and Regulating Vault.

TABLE I. of Blowing Cylinders, their Capacity, Area, and Quantity of Air discharged by a Four-Feet Stroke, &c.

Diameter of Cylinders in Inches	Area in Circular Inches.	Area in Square Inches	Capacity of the Stroke in Cubic Feet.	Air discharged at the Rate of 50 Cylinders per Minute.	Air discharged at the Rate of 40 Cylinders per Minute.	Air discharged at the Rate of 30 Cylinders per Minute.	Air discharged at the Rate of 25 Cylinders per Minute.	Air discharged at the Rate of 20 Cylinders per Minute.	Air discharged at the Rate of 15 Cylinders per Minute.	Air discharged at the Rate of 12 Cylinders per Minute.	Air discharged at the Rate of 10 Cylinders per Minute.
36	1296	1017.8784	28.2744	1413.7200	1130.9760	848.2320	706.8600	565.4880	424.1160	339.2928	282.7440
37	1369	1075.8670	29.8670	1493.3500	1194.6800	896.0100	746.6750	597.3400	448.0050	358.4040	298.6700
38	1444	1134.1176	31.5032	1575.1600	1260.1280	945.0960	787.5800	630.1280	472.5480	378.0384	315.0320
39	1521	1194.5934	33.1831	1659.1550	1327.3240	995.4930	829.5775	663.6620	497.7465	398.1972	331.8310
40	1600	1256.6400	34.9055	1745.2750	1396.2200	1047.1650	872.6375	698.1100	523.5825	418.8650	349.0550
41	1681	1320.2574	36.6738	1833.6900	1466.9520	1100.2140	916.8450	733.4760	550.1020	440.0856	366.7380
42	1764	1385.4456	38.4834	1924.1700	1539.3360	1154.5020	962.0850	769.6680	577.2510	461.8008	384.8340
43	1849	1452.2046	40.3390	2016.9500	1613.5600	1210.1700	1008.4750	806.7800	605.0850	484.0680	403.3900
44	1936	1520.5344	42.2370	2111.8500	1689.4800	1267.1100	1055.9250	844.7400	633.5550	506.8440	422.3700
45	2025	1590.4350	44.1787	2208.9350	1767.1480	1325.3610	1104.4765	883.5740	662.6805	530.1444	441.7870
46	2116	1661.9064	46.1640	2308.2090	1846.5600	1384.9200	1154.1000	923.2800	692.4600	553.9680	461.6400
47	2209	1734.9486	48.1930	2409.6500	1927.7200	1445.7900	1204.8750	963.3600	772.8950	578.3160	481.9300
48	2304	1809.5616	50.2656	2513.2800	2010.6240	1507.9680	1256.6400	1005.3120	753.9840	603.1872	502.6560
49	2401	1885.7545	52.3818	2619.0900	2095.2720	1571.4540	1309.5450	1047.6360	785.7270	628.5816	523.8180
50	2500	1963.5000	54.5416	2727.0800	2181.6640	1636.2480	1363.5400	1090.8320	8[illegible]8.1240	654.4992	545.4160
51	2601	2042.8254	56.7451	2837.2550	2269.8040	1702.3530	1418.6275	11[illegible]4.9020	851.1760	680.9412	567.4510
52	2704	2123.7216	58.9644	2948.2200	2358.5760	1768.9320	1474.1100	1179.2800	884.4660	707.5728	589.6440
53	2809	2206.1886	61.2830	3064.1500	2451.3200	1838.4900	1532.0750	1220.6600	919.2450	735.3960	612.8300
54	2916	2290.2264	63.6173	3180.8650	2544.6920	1908.5190	1590.4327	1272.3410	954.2595	763.4076	636.1730
55	3025	2375.8350	65.9954	3299.7700	2639.8160	1979.8620	1649.8850	1319.9080	989.9310	791.9418	659.9540
56	3136	2463.0144	68.4017	3420.5350	2736.4280	2052.3210	1710.2675	1363.2140	1026.1605	820.9284	684.1070
57	3249	2551.7646	70.8823	3544.1150	2835.2920	2126.4690	1772.0575	417.6460	1063.2345	850.5876	708.8230
58	3364	2642.0856	73.3913	3669.5650	2935.6520	2201.7390	1834.7825	1467.8260	1100.8695	880.6956	733.9130
59	3481	2733.9774	75.9438	3797.1900	3037.7520	2278.3140	1898.5950	1518.8760	1139.1520	911.3256	759.4380
60	3600	2827.4400	78.5400	3927.0020	3141.6000	2356.2000	1963.5000	1570.8000	1178.1000	942.4800	785.4000
61	3721	2922.4734	81.1798	4058.9900	3247.1920	2435.3740	2029.9950	623.5960	1217.6870	974.1576	811.7980
62	3844	3019.0776	83.8632	4193.1500	3354.5280	2515.8960	2096.5750	1677.2640	1257.9480	1006.3584	838.6320
63	3969	3117.2526	86.5703	4325.3650	3462.8120	2597.1090	2162.6[illegible]25	1731.4060	1208.5545	1038.8436	865.7030
64	4096	3216.9984	89.3332	4466.6600	3573.3280	2679.9960	2233.3300	1786.6640	1339.9980	1071.9984	893.3320
65	4225	3318.3150	92.1751	4608.7200	3687.0160	2765.2[illegible]20	2304.3600	1843.5080	1382.6300	1106.0848	921.7540
66	4356	3421.2024	95.0334	4751.6700	3801.3360	2850.9020	2375.8350	1900.1680	1425.4510	1140.4008	950.0840
67	4489	3525.6606	97.9350	4895.7500	3917.4000	2938.0500	2498.3750	1958.7000	1469.0250	1175.2200	979.3500
68	4624	3631.6896	100.8802	5044.0100	4035.2080	3026.4060	2552.8050	2017.6040	1513.2030	1210.5624	[illegible]08.8020
69	4761	3739.2894	103.8691	5193.4550	4154.7640	3116.0730	2596.7275	2077.3800	1558.0365	1246.4292	1038.6900
70	4900	3848.4600	106.9017	5345.0850	4276.0680	3207.0510	2672.5425	2138.0340	1603.5255	1282.8204	1069.0170
71	5041	3959.2014	109.9778	5498.8000	4399.1120	3299.3340	2749.4450	2199.5560	1649.6620	1319.7336	1099.7780
72	5184	4071.5136	113.0976	5654.8800	4523.9040	3392.9280	2827.4400	2261.9520	1696.4640	1357.1512	1130.9760
73	5329	4185.39[illegible]6	116.2610	5813.0500	4650.4400	3487.8300	2906.5250	2325.2200	1743.9150	1395.1320	1162.6[illegible]00
74	5476	4300.8504	119.4600	5973.4000	4778.7200	3584.0400	2986.7000	2389.3600	1792.0200	1433.6160	1194.6[illegible]00
75	5625	4417.8750	122.7187	6135.9350	4908.7480	36[illegible]1.561[illegible]	3067.9675	2454.3740	1840.7805	1472.6244	1277.1870
76	5776	4536.4704	126.0130	6301.5500	5040.5200	3780.3900	3150.7750	2520.2600	1890.1950	1512.1560	1260.1300
77	5929	4656.6366	129.3232	6466.1600	5172.9280	3879.6960	3233.0800	2586.4640	1939.8480	1551.8784	1293.2320
78	6084	4778.3736	132.7326	6633.6300	5309.3040	39[illegible]1.9780	3316.8150	2654.6520	1990.4890	1592.7912	1327.3760
79	6241	4901.6[illegible]14	136.1578	6807.8900	5446.3120	4084.7340	3403.9450	2723.1560	2042.3670	1633.8936	1366.5780
80	6400	5026.5600	139.6266	6981.3300	5585.0640	4188.7980	3490.6650	2792.5320	2094.3990	1675.5192	1396.2660
81	6561	5153.0094	143.1391	7156.9550	5725.5640	4294.1730	3578.4775	2862.7820	2147.0865	1717.6692	1431.3910
82	6724	5281.0296	146.6952	7334.7600	5867.8080	4400.8560	3667.3800	2938.9040	2200.4280	1760.3424	1469.4520
83	6889	5410.5206	150.2950	7514.7500	6011.8000	4508.8500	3757.3750	3055.4000	2254.4250	1803.5400	1527.7000
84	7056	5541.7824	153.9386	7696.9300	6157.5440	4618.1580	3848.4650	3078.7720	2309.0790	1847.5048	1539.8860
85	7225	5674.5150	157.6254	7881.2700	6305.0160	4728.7620	3940.6350	3152.5080	2364.3810	1891.5048	1576.2540
86	7396	5803.8184	161.3560	8067.8000	6453.2400	4840.6800	4033.9000	3226.6200	2420.3400	1936.2720	1613.3100
87	7569	5944.6920	65.1303	8256.5150	6605.2120	4953.9090	4128.2575	3302.6068	2476.9545	1981.5630	1651.3030
88	7744	6082.1376	168.9482	8447.4100	6757.9280	5068.4460	4223.7050	3378.9640	2534.2230	2027.3784	1089.4820
89	7921	6221.1534	172.8098	8540.4900	6912.3920	5184.2940	4270.2450	3456.1960	2592.1470	2073.7186	1728.0980
90	8100	6361.7400	176.7150	8835.7500	7068.6000	5301.4500	4417.8750	3534.3000	2650.7250	2120.5800	1767.1500
91	8281	6503.897[illegible]	80.6638	9033.1900	7226.5520	5419.9140	4516.5950	3613.2760	2709.9570	2167.9656	1806.6380
92	8464	6647.6[illegible]56	84.6562	9232.8100	7386.2480	5539.6860	4616.4550	3693.1240	2769.8430	2264.3076	1846.0620
93	8649	6792.9246	88.6923	9434.6150	7547.6920	5660.7690	4717.3075	3773.8460	2830.3845	2313.2640	1886.4230
94	8836	6939.7944	192.7720	9638.6000	7709.8800	5783.160	4819.3000	3854.9400	2891.5800	2362.7448	1927.4700
95	9025	7088.2350	196.8954	9844.7700	7875.8160	5906.8620	4922.3850	3937.9080	2953.4310	2412.7512	1968.9540
96	9216	7238.2464	201.0626	10053.1300	8042.5040	6031.8780	5026.5650	4021.2520	3015.9390	2463.2760	2010.6260
97	9409	7389.8286	2[illegible]5.2730	10263.6500	8210.9200	6158.1900	5131.8250	4105.4600	3079.0950	2514.3254	2002.7300
98	9604	7542.9816	209.5272	10[illegible]76.3600	8381.0880	6285.8160	5238.1800	4190.5440	3147.9080	2565.9012	2095.2720
99	9801	7697.7054	213.8251	10691.2550	8553.0040	6414.7530	5345.6275	4276.5020	3207.3765	2215.8744	2138.2510
100	10000	7854.0000	218.1666	10908.3300	8726.6640	6544.9980	5454.1650	4363.3320	3272.4990	2617.9992	2181.6660

TABLE II. of blowing Cylinders, their Area, Capacity, and Quantity of Air, discharged by a Five-Feet Stroke.

Diameter of Cylinders.	Area in Circular Inches.	Area in Square Inches.	Capacity of the Stroke in Cubical Feet.	Air discharged at the Rate of 50 Cylinders per Minute, in Cubical Feet.	Air discharged at the Rate of 40 Cylinders per Minute in Cubical Feet.	Air discharged at the Rate of 30 Cylinders per Minute in Cubical Feet.	Air discharged at the Rate of 25 Cylinders per Minute in Cubical Feet.	Air discharged at the Rate of 20 Cylinders per Minute in Cubical Feet.	Air discharged at the Rate of 15 Cylinders per Minute in Cubical Feet	Air discharged at the Rate of 12 Cylinders per Minute in Cubical Feet.	Air discharged at the Rate of 10 Cylinders per Minute in Cubical Feet.
36	1296	1017.8784	35.3430	1767.1500	1413.7200	1060.2900	883.5750	706.8600	530.1450	424.1100	353.4300
37	1369	1075.8670	37.3337	1866.6850	1493.3480	1120.0110	933.3425	746.6740	560.0055	448.0044	373.3370
38	1444	1134.1176	39.3790	1968.9500	1575.1600	1181.3700	984.4750	787.5800	590.6850	472.5480	393.7900
39	1521	1194.5984	41.4788	2073.9400	1659.1520	1244.3640	1036.9700	829.5760	622.1820	497.7456	414.7880
40	1600	1256.6400	43.6319	2181.5950	1745.2760	1308.9570	1090.2975	872.6380	654.4785	523.5828	436.3190
41	1681	1320.2574	45.8422	2292.1100	1833.6880	1375.2660	1146.0550	916.8440	687.6330	550.1064	458.4220
42	1764	1385.4456	48.1042	2405.2100	1924.1680	1443.1260	1202.6050	962.0840	721.5630	577.2504	481.0420
43	1849	1452.2046	50.4237	2521.1850	2016.9480	1512.7110	1260.5925	1008.4740	756.3550	605.0844	504.2370
44	1936	1520.5344	52.7962	2639.8100	2111.8480	1583.8860	1319.9050	1055.924	791.9430	633.5544	527.9620
45	2025	1590.4350	55.2233	2761.1650	2208.9320	1656.6990	1380.5825	1104.4660	828.3495	662.6796	552.2330
46	2116	1661.9064	57.7050	2885.2500	2308.2000	1731.1500	1442.6250	1154.1000	865.5750	692.4600	577.0500
47	2209	1734.9486	60.2412	3012.0600	2409.6480	1807.2360	1506.0300	1204.8240	903.6180	722.8944	602.4120
48	2304	1809.5616	62.8320	3141.6000	2513.2800	1884.9600	1570.8000	1256.6400	942.4800	753.9840	628.3200
49	2401	1885.7545	65.4772	3273.8600	2619.0880	1964.3160	1636.4300	1309.5440	982.1580	785.7264	654.7720
50	2500	1963.5000	68.1770	3408.8500	2727.0800	2045.3100	1704.4250	1363.5400	1022.6550	818.1240	681.7700
51	2601	2042.8254	70.9313	3546.5650	2837.2520	2127.9390	1773.2825	1418.6260	1063.9695	851.1756	709.3130
52	2704	2123.7216	73.7055	3685.2750	2948.2200	2211.1650	1842.6375	1474.1100	1105.5825	884.4660	737.0550
53	2809	2206.1886	76.6037	3830.1850	3064.1480	2298.1110	1915.0925	1532.0740	1149.0550	919.2444	761.0370
54	2916	2290.2264	79.5216	3976.0800	3180.8640	2385.6480	1988.0400	1590.4320	1192.8240	954.2592	795.2160
55	3025	2375.8350	82.4942	4124.7100	3299.7680	2474.8260	2062.3550	1649.8840	1237.4130	989.9304	824.9420
56	3136	2463.0144	85.5021	4275.1050	3420.0840	2565.0630	2137.5525	1710.0420	1282.5315	1026.0242	855.0210
57	3249	2551.7646	88.6028	4430.1400	3544.1120	2658.0840	2215.0700	1772.0560	1329.0420	1063.2336	886.0280
58	3364	2642.0856	91.7391	4586.9550	3669.5640	2752.1730	2293.4775	1834.7820	1376.0865	1100.8692	917.3910
59	3481	2733.9774	94.9297	4746.4850	3797.1880	2847.8910	2373.2425	1898.5940	1423.9455	1139.1564	949.2970
60	3600	2827.4400	98.1750	4908.7500	3927.0000	2945.2500	2454.3750	1963.5000	1472.6250	1178.1000	981.7500
61	3721	2922.4734	101.4747	5073.7350	4058.9880	3044.2410	2536.8675	2029.4940	1522.1205	1217.6924	1014.7470
62	3844	3019.0776	104.8290	5241.4500	4193.1600	3144.8700	2620.7250	2096.5800	1572.4350	1257.9480	1048.2900
63	3969	3117.2526	108.2128	5410.6400	4328.5120	3246.3840	2705.3200	2164.2560	1623.1920	1298.5536	1082.1280
64	4096	3216.9984	111.6665	5583.3250	4466.6600	3349.9950	2791.6125	2233.3300	1674.9975	1339.9980	1116.6650
65	4225	3318.3150	115.2192	5760.9600	4608.7680	3456.5760	2830.4500	2304.3840	1728.2880	1382.6304	1152.1920
66	4356	3421.2024	118.7927	5939.6350	4751.7080	3563.7810	2969.8175	2375.8540	1781.8905	1425.5124	1187.9270
67	4489	3525.6506	122.4187	6120.9350	4896.7480	3672.5610	3060.4675	2498.3740	1836.2805	1469.0244	1249.1870
68	4624	3631.6896	126.1002	6305.0100	5044.0080	3783.0060	3152.5050	2522.0040	1891.5030	1513.2024	1261.0020
69	4761	3739.2894	129.8363	6491.8150	5193.4520	3895.0890	3245.9075	2596.7260	1947.5445	1558.0356	1298.3630
70	4900	3848.4600	133.6271	6681.3550	5345.0840	4008.8130	3340.6775	2072.5420	2004.4065	1603.5252	1336.2710
71	5041	3959.2014	137.4722	6873.6100	5498.8880	4124.1660	3436.8050	2749.4440	2062.0830	1649.6664	1374.7220
72	5184	4071.5136	141.3720	7068.6000	5654.8800	4241.1600	3534.3000	2827.4400	2120.5800	1696.4640	1413.7200
73	5329	4185.3966	145.3262	7266.3100	5813.0480	4359.7860	3633.1550	2906.5240	2179.8930	1743.9144	1453.2620
74	5476	4300.8504	149.3350	7466.7500	5973.4000	4480.0500	3733.3750	2986.7000	2240.0250	1792.0200	1493.3500
75	5625	4417.8750	153.3983	7669.9150	6135.9380	4601.9490	3834.9575	3067.9690	2300.9745	1840.1796	1533.9845
76	5776	4536.4704	157.5162	7875.8100	6300.6480	4725.4860	3937.9050	3150.3240	2367.7430	1890.1944	1575.1620
77	5929	4656.6366	161.6540	8082.7000	6466.1600	4849.6200	4041.3500	3233.0800	2424.8100	1939.8480	1616.5400
78	6084	4778.3736	165.9157	8295.7850	6636.6280	4977.4710	4147.8925	3318.3140	2488.7350	1990.9874	1659.1570
79	6241	4901.6814	170.1972	8509.8600	6807.8880	5105.9160	4254.9300	3403.9440	2552.9580	2042.3664	1701.9720
80	6400	5026.5600	174.5332	8726.6600	6981.3280	5235.9960	4363.3300	3490.6640	2607.9980	2094.3984	1745.3320
81	6561	5153.0094	178.9238	8946.1900	7156.9520	5367.7140	4473.0950	3578.4760	2683.8570	2147.0856	1789.2380
82	6724	5281.0296	183.3690	9168.4500	7334.7600	5501.0700	4584.2250	3667.3800	2750.5350	2200.4283	1833.6900
83	6889	5410.6206	187.8697	9393.4850	7514.7480	5636.0610	4696.7175	3757.3740	2818.0305	2254.4244	1878.6870
84	7056	5541.7824	192.4232	9621.1600	7696.9280	5772.6960	4810.5800	3848.4640	2886.3480	2309.0784	1924.2320
85	7225	5674.5150	197.0317	9851.5850	7881.1268	5910.9510	4925.7925	3940.6340	2955.4755	2364.3804	1970.3170
86	7396	5808.3184	201.6950	10084.7500	8067.8000	6050.8500	5042.3750	4033.9000	3025.4250	2420.3400	2016.9500
87	7569	5944.6926	206.4128	10320.6400	8256.5120	6192.3840	5160.3200	4128.2560	3096.1920	2476.9536	2064.1280
88	7744	6082.1576	211.1852	10559.2600	8447.4080	6335.5500	5279.6300	4223.7540	3167.7780	2534.2224	2111.8770
89	7921	6221.1534	216.0122	10800.6100	8640.4880	6480.3660	5400.3050	4320.2440	3240.1880	2592.1464	2160.1220
90	8100	6361.7400	220.8937	11044.6850	8835.7430	6626.8110	5522.3425	4417.8740	3313.4055	2650.7244	2208.9370
91	8281	6503.8974	225.8297	11291.4850	9033.1880	6774.8910	5645.7425	4516.5940	3387.4450	2709.9554	2258.2970
92	8464	6647.6256	230.8656	11543.2800	9234.6240	6925.9680	5771.6400	4617.3120	3462.4840	2770.3872	2308.6560
93	8649	6792.9240	235.8653	11793.2650	9434.6120	7075.9590	5896.6325	4717.3060	3587.9795	2830.3836	2358.6530
94	8836	6939.7944	240.9560	12047.8000	9638.2400	7228.6800	6023.9000	4819.1200	3614.3400	2891.4720	2409.5600
95	9025	7088.2350	246.1187	12305.9350	9844.7480	7383.5610	6152.9675	4922.3740	3691.7805	2953.4244	2461.3740
96	9216	7238.2464	251.3282	12566.4100	10053.1280	7539.8460	6283.2050	5026.5640	3764.9230	3015.9384	2513.2820
97	9409	7389.8256	256.5912	12829.5600	10263.6480	7697.7360	6414.7800	5131.8240	3848.8680	3079.0944	2565.9120
98	9604	7542.9816	261.9090	13095.4500	10476.3600	7857.5700	6547.7250	5238.6800	3928.7850	3142.9080	2619.3400
99	9801	7697.7054	267.2813	13364.0650	10691.2520	8018.4390	6682.0325	5345.6260	4009.2195	3207.3756	2672.3130
100	10000	7854.0000	272.7082	13635.4100	10908.3280	8181.2460	6817.7050	5454.1640	4090.1230	3272.4984	2727.0820

TABLE III. of Blowing Cylinders, their Area, Capacity, and Quantity of Air difcharged by a Six-Feet Stroke.

Diameter of Cylinders	Area in Circular Inches	Area in Square Inches	Capacity of the Stroke in Cubical Feet	Air difcharged at the Rate of 50 Cylinders per Minute in Cubical Feet	Air difcharged at the Rate of 40 Cylinders per Minute in Cubical Feet	Air difcharged at the Rate of 30 Cylinders per Minute in Cubical Feet	Air difcharged at the Rate of 25 Cylinders per Minute in Cubical Feet	Air difcharged at the Rate of 20 Cylinders per Minute in Cubical Feet	Air difcharged at the Rate of 15 Cylinders per Minute in Cubical Feet	Air difcharged at the Rate of 12 Cylinders per Minute in Cubical Feet	Air difcharged at the Rate of 10 Cylinders per Minute in Cubical Feet
36	1296	1017.8784	42.4116	2120 5800	1696.4640	1272.3480	1060.2900	848.2320	636.1740	508.9392	424.1160
37	1369	1075.8670	44.8005	2240.0250	1792.0200	1344.0150	1120.0125	896.0100	672.0075	537.6060	448.0050
38	1444	1134.1176	47.2548	2362.7400	1890 1920	1417.6440	1181.3700	945.0960	708.8220	567.0576	472.5480
39	1521	1194.5934	49.7746	2488.7300	1990 9840	1493.2380	1244.3650	995.4920	746.6190	597.2952	497.7460
40	1600	1256.6400	52.3582	2617 9100	2094.3280	1570.7460	1308.9550	1047.1640	785.3730	628.2986	523.5820
41	1681	1320.2574	55.0107	2750.5350	2200.4280	1650.3210	1375.2675	1100.2140	825.1605	660.1284	550.1070
42	1764	1385.4456	57.7251	2886.2550	2309.0040	1731.7530	1443.1275	1154.5020	865.8765	692.7012	574.2510
43	1849	1452.2046	60.5085	3025.4250	2420.3400	1815.2550	1512.7125	1210 1740	907 6275	726.1020	605 0870
44	1936	1520.5344	63 3555	3167.7750	2534.2200	1900.6650	1583.8875	1267.1100	950.3325	760.2660	638.5500
45	2025	1590.4350	66.2680	3313.4000	2650.7200	1988.0400	1656.2000	1325.3600	999 0200	795.1960	662.6800
46	2116	1661.9064	69.2460	3462.3000	2769.8400	2077.3800	1731.1500	1384.4200	1038.6900	830.9520	692.2100
47	2209	1734.9486	72.2895	3614.4750	2891.5800	2168.6850	1807.2375	1445.2900	1084.3425	867.4740	722.6450
48	2304	1809.5616	75.3984	3769.9200	3015 9360	2261.9520	1834.9600	1507.9680	1130.9760	904.7808	753.9840
49	2401	1885.7545	78.5727	3928.6350	3142.9080	2357.1810	1964.3175	1571.4540	1178.5950	942.8724	785.7270
50	2500	1963.5000	81.8124	4090.6200	3272.4960	2454.3720	2045.3100	1636.4980	1227 6860	981.7488	818.2490
51	2601	2042.8254	85.1176	4255.8800	3404.7040	2553.5280	2127.9400	1702.3520	1276.7640	1024.4112	851.1760
52	2704	2123.7216	88.4466	4422.3300	3537.8640	2653.3980	2211.1650	1768.9320	1326.6940	1061.5592	884.4660
53	2809	2206.1886	91.9246	4596.2300	3676.9840	2757.7380	2298.1150	1838.4920	1378.8690	1103.0952	919.4920
54	2916	2290.2264	95.4259	4771.2950	3817.0360	2862.7770	2385.6475	1908.5180	1431.3885	1143.1108	954.2590
55	3025	2375.8350	98.9931	4949.6550	3959.7240	2969.7930	2474.8275	1979.8620	1484.8965	1187.9172	989.9310
56	3136	2463.0144	102.6025	5130.1250	4104.1000	3078.0750	2565.0625	2052.0500	1539.0375	1231.2300	1026.0250
57	3249	2551.7646	106.3234	5316.1700	4252.9360	3189.7020	2608.0850	2126.4680	1594.3510	1275.8604	1063.2340
58	3364	2642.0856	110.0869	5504.3450	4402.7560	3302.6070	2752.1725	2201.3780	1651.3035	1321.0428	1100.6890
59	3481	2733.9774	113.9157	5695.7850	4556.6280	3417.4710	2847.8925	2278.3140	1708.7355	1366.9884	1139.1570
60	3600	2827.4400	117.8100	5890,5000	4712.400	3534.3000	2945.2500	2356.2000	1767.1500	1413.7200	1178.1000
61	3721	2922.4734	121.7697	6088.4850	4870.7800	3653.0910	3044.2425	2435.3900	1826.5450	1461.2364	1217.6950
62	3844	3019 0776	125.7948	6289.7400	5031.7920	3773.8440	3144.8700	2515.8960	1886.9220	1509.5376	1257.9480
63	3969	3117.2526	129.8544	6492.7200	5194.1640	3895.6320	3246.3600	2592.0820	1947.8160	1558.2528	1296.0410
64	4096	3216.9984	133.9998	6699 9900	5359 9920	4019.9940	3349.9950	2679.9960	2009.9970	1609.9976	1339.9980
65	4225	3318.3150	138.2631	6913.1550	5530.5240	4147.8930	3456.5750	2765.2620	2073 9465	1659.1572	1382.6310
66	4356	3421.2024	142.5501	7127.5050	5702.0040	4276.5030	3563.7525	2851.0020	2138.2515	1710.6012	1425 5010
67	4489	3525.6606	146 9025	7345.1250	5876.1090	4407 0750	3672.5625	2938 0500	2203 5375	1762.8300	1469 0250
68	4624	3631 6896	151.3203	7566.0150	6052.8120	4539.6090	3783.0075	3026.4060	2269 8045	1815.8436	1513.2030
69	4761	3739.2894	155.8036	7790.1800	6232.1440	4674.1080	3895.0900	3116.0720	2337.0540	1869.6432	1558 0360
70	4900	3848.4600	160.3525	8017.6250	6414.1000	4810.5750	4008.8125	3207.0500	2405.2875	1924.2300	1603.5250
71	5041	3959.2014	164.9667	8248.3350	6598.6680	4949.0010	4124.1675	3299.3340	2474.5050	1979.6004	1649.6670
72	5184	4071.5136	169.6464	8482.3200	6785.8560	5089.3920	4241.1600	3392.9280	2544.6960	2035.7568	1696.4640
73	5329	4185.3966	174.3915	8719.5750	6975.6600	5231.7450	4359.7875	3487.8300	2615.8725	2092.6980	1743.9150
74	5476	4300.8504	179.2020	8960.1000	7168 0800	5376.0600	4480 0500	3584.0400	2688.0300	2150.4240	1792.0200
75	5625	4417.8750	184.0780	9203.9000	7363.1200	5522.3400	4601.9500	3681.5600	2761.1700	2208.0360	1840.7800
76	5776	4536.4704	189.0195	9450.9750	7560.7800	5670 5850	4725.4875	3780.3900	2835.2925	2268.2340	1890.1950
77	5929	4656.6366	193.9848	9699.2400	7759.3920	5819.5440	4849.6200	3879.6960	2909.7720	2327.8176	1939.8480
78	6084	4778.3736	199.0989	9954.9490	7963.9560	5972.9670	4977.4745	3981.9780	2986.4835	2399.1868	1990.9890
79	6241	4901.6814	204.2367	10211.8350	8169.4680	6127.1010	5105.9175	4034.7340	3063.5505	2450.8404	2017.3670
80	6400	5026.5600	209.4399	10471.9950	8377.5960	6283.1970	5235.9975	4188.7980	3141.5985	2513.2788	2094.3990
81	6561	5153.0094	214.7086	10735.4300	8588.3440	6441.2580	5367.7150	4294.1720	3220.1290	2576.5032	2147.086
82	6724	5281.0296	220 0428	11002.1400	8801.7120	6601.2840	5501.0700	4400.3560	3300.6420	2640.5136	2200.1780
83	6889	5410.6206	225.4425	11272.1250	9017.7000	6763.2750	5636.0625	4508.8500	3381.6375	2705.3100	2254.4250
84	7056	5541.7824	230.9079	11545.3950	9236.3160	6927.2370	5772.6975	4618.1580	3463.6185	2770.8948	2309.0790
85	7225	5674.5150	236.4381	11821.9050	9457.5240	7093.1430	5910.9525	4728.7620	3546.5715	2837.2572	2364.3810
86	7396	5808.8184	242.0340	12101.7000	9681.3600	7261.0200	6050.8500	4840.1800	3630.5100	2904.4080	2420.0900
87	7569	5944.6926	247.6954	12384 7700	9907 8160	7430.8620	6192.3850	4953.9080	3715.4310	2972.3448	2476.9540
88	7744	6082.1376	253.4223	12671.1150	10136.8920	7602.6690	6335.5575	5068.4460	3801.3345	3041.0676	2534.2230
89	7921	6221.1534	259.2147	12960.7350	10368.5880	7776.4410	6480.3675	5184.2940	3883.2205	3110.5764	2592.1470
90	8100	6361.7400	265.0725	13253.6250	10602.9000	7952.1750	6626.8125	5301.4500	3976.0875	3180.8700	2650.7250
91	8281	6503.8974	270.9957	13549.7850	10839.8280	8129.8710	6774.8925	5419.9140	4064.9350	3251.9484	2709.9570
92	8464	6647.6256	276.9843	13849.2150	11079.3720	8309.5290	6924.6075	5539.6860	4154.7645	3323.8116	2769.8430
93	8649	6792.9246	283.0384	14151 9200	11321.5360	8491.1520	7075.9600	5660.7680	4245.5760	3376.4608	2830.3840
94	8836	6939.7944	289.1580	14457.9000	11566.3200	8674.7400	7228.4500	5783.1600	4337.3700	3469.8960	2891.5800
95	9025	7088.2350	295.3431	14767.1550	11813.7240	8860.2930	7383.5750	5906.8620	4430.1465	3544.1172	2953.4310
96	9216	7238.2464	301.5939	15079.6950	12063.7560	9047.8170	7539.8475	6031.8780	4523.9085	3619.1268	3015.9390
97	9409	7542.9816	307.9095	15395.4750	12316.3800	9237.2850	7697.7375	6158.1900	4618.6475	3694 9140	3079.0950
98	9604	7389.8286	314.3008	15715.0400	12572.0320	9429 0240	7857.5200	6286.0160	4714.5120	3771.6096	3143.0080
99	9801	7697.7054	320.7376	16036.8800	12829.5040	9622.1280	8018.4400	6414.7520	4811.0640	3848.8512	3207.3760
100	10000	7854 0000	327.2499	16362.4950	13089.9960	9817.4970	8181.2475	6544.9980	4908.7485	3926.9988	3272.4990

TABLE IV. of Blowing Cylinders, their Area, Capacity, and Quantity of Air discharged by a Seven-Feet Stroke.

Diameters of Cylinders.	Area in Circular Inches.	Area in Square Inches.	Capacity of the Stroke in Cubical Feet.	Air discharged at the Rate of 50 Cylinders per Minute in Cubical Feet.	Air discharged at the Rate of 40 Cylinders per Minute in Cubical Feet.	Air discharged at the Rate of 30 Cylinders per Minute in Cubical Feet.	Air discharged at the Rate of 25 Cylinders per Minute in Cubical Feet.	Air discharged at the Rate of 20 Cylinders per Minute in Cubical Feet.	Air discharged at the Rate of 15 Cylinders per Minute in Cubical Feet.	Air discharged at the Rate of 12 Cylinders per Minute in Cubical Feet.	Air discharged at the Rate of 10 Cylinders per Minute in Cubical Feet.
36	1296	1017.8784	49.4702	2473.5100	1978.8080	1484.1060	1236.7550	989.4040	742.0530	593.6424	494.7020
37	1369	1075.8670	52.2672	2613.3600	2090.6880	1568.0160	1306.6800	1045.3440	784.0080	627.2064	522.6720
38	1444	1134.1176	55.1306	2756.5300	2205.2240	1653.9180	1378.2650	1102.6120	826.9590	661.5672	551.3060
39	1521	1194.5934	58.0705	2903.5250	2322.8200	1742.1150	1451.7625	1161.4100	871.0575	696.8460	580.7050
40	1600	1256.6400	61.0845	3054.2250	2443.3800	1832.5350	1527.1125	1221.6900	916.2675	733.0140	610.8450
41	1681	1320.2574	64.1791	3208.9550	2567.1640	1925.3730	1604.4775	1283.5820	912.6865	770.1492	641.7910
42	1764	1385.4456	67.3459	3367.2950	2693.8360	2020.3770	1683.6475	1346.9180	1010.1885	808.1508	673.4590
43	1849	1452.2046	70.5932	3529.6600	2823.7280	2117.3300	1764.8300	1411.8640	1058.6650	847.1184	705.9320
44	1936	1520.5344	73.9110	3695.5500	2936.4400	2217.3300	1847.7750	1468.2200	1108.6600	886.9320	734.1100
45	2025	1590.4350	77.3126	3865.6300	3092.5040	2319.3780	1932.8150	1546.2520	1159.6890	927.7512	773.1260
46	2116	1661.9064	80.7870	4039.3500	3231.4800	2423.6100	2019.6750	1615.7400	1211.8050	969.4440	807.8700
47	2209	1734.9486	84.3377	4216.8850	3373.5080	2530.1310	2108.4425	1686.7540	1265.0655	1012.0524	843.3750
48	2304	1809.5616	87.9648	4398.2400	3518.5920	2638.9440	2199.1200	1759.2960	1319.4720	1055.5776	879.6480
49	2401	1885.7545	91.6681	4584.4050	3666.7240	2750.0430	2292.2050	1833.3620	1375.0215	1100.0172	916.6810
50	2500	1963.5000	95.4478	4772.3900	3817.9120	2863.4340	2386.1950	1908.9560	1431.2120	1145.3736	954.4780
51	2601	2042.8254	99.3038	4965.4400	3972.1520	2979.1140	2482.7200	1986.0760	1489.5570	1191.6456	993.0380
52	2704	2123.7216	103.1877	5159.3850	4127.5080	3095.6310	2579.6925	2063.7540	1547.8150	1238.2524	1031.8770
53	2809	2206.1886	107.2453	5362.2650	4289.8120	3217.3590	2681.1325	2144.9060	1608.1795	1286.9436	1072.4530
54	2916	2290.2264	111.3302	5566.5100	4453.2080	3339.9060	2783.2550	2226.6040	1669.9530	1335.9624	1113.3020
55	3025	2375.8350	115.4919	5774.5950	4619.6760	3464.7570	2887.2975	2309.8380	1732.3785	1385.9028	1154.9140
56	3136	2463 0144	119.7029	5985.1450	4788.1160	3591.0870	2992.5725	2394.0580	1795.5435	1436.4348	1197.0290
57	3249	2551.7646	124.0439	6202.1950	4961.7560	3721.3170	3101.0975	2480.8780	1860.6585	1488.5268	1240.4390
58	3364	2642.0856	128.4347	6421.7350	5137.3880	3853.0410	3210.8675	2568.6940	1926.5205	1541.2164	1284.3470
59	3481	2733.9774	132.9016	6645.0800	5316.0640	3987.0480	3322.5400	2658.0320	1993.5240	1594.8192	1329.0160
60	3600	2827.4400	137.4450	6872.2500	5497.8000	4123.3500	3436.1250	2748.4000	2061.6750	1649.3400	1374.2000
61	3721	2922.4734	142.0646	7103.2300	5682.5840	4261.9380	3551.6150	2841.2920	2130.9690	1704.7752	1420.6460
62	3844	3019.0776	146.7606	7338.0300	5870.4240	4402.8180	3669.0150	2935.2120	2201.4090	1761.1272	1467.6060
63	3969	3117.2526	151.4968	7574.8400	6059.8720	4544.9040	3787.4200	3029.9360	2272.4520	1817.9616	1514.9680
64	4096	3216.9984	156.3331	7816.6550	6253.3240	4689.9930	3908.3275	3126.6620	2344.9965	1875.9972	1563.3310
65	4225	3318.3150	162.1664	8108.3200	6486.6560	4864.9920	4054.1600	3243.3280	2432.4960	1945.9968	1621.6640
66	4356	3421.2024	166.3084	8315.4400	6652.3360	4989.2520	4157.7200	3326.1630	2494.6260	1995.7008	1663.0815
67	44 9	3525.6606	171.3862	8569.3100	6855.4480	5141.5860	4284.6500	3427.7240	2570.7930	2056.6344	1713.8620
68	4624	3631.6896	176.5403	8827.0150	7061.6120	5296.2090	4413.5075	3530.8060	2648.1045	2118.4836	1765.4030
69	4761	3739.2894	181.7708	9088.5400	7270.8320	5453.1240	4544.2700	3635.4160	2726.5620	2181.2496	1817.7080
70	4900	3848.4600	187.0779	9353.8950	7483.1160	5612.3370	4676.9475	3741.5580	2806.1685	2244.9348	1870.7790
71	5041	3959.2014	192.4611	9623.0550	7698.4440	5773.8330	4811.5275	3849.2220	2886.9165	2309.5332	1929.6110
72	5184	4071.5136	197.9210	9896.0500	7916.8400	5937.6300	4948.0250	3958.4200	2968.8150	2375.0520	1979.2100
73	5329	4185.3966	203.4567	10172.8350	8138.2680	6103.7010	5086.4175	4069.1340	3051.8505	2441.4804	2034.5670
74	5476	4300.8504	209.0690	10453.4500	8362.7600	6272.0700	5226.7250	4181.3800	3136.0350	2508.8280	2090.1900
75	5625	4417.8750	214.7576	10737.8800	8590.3040	6442.7280	5368.9400	4295.1520	3221.3640	2577.0912	2147.5760
76	5776	4536.4704	220.5227	11026.1350	8820.9080	6615.6810	5513.0675	4410.4540	3307.8405	2046.2724	2205.2270
77	5929	4656.6366	226.3156	11315.7800	9052.6240	6789.4680	5657.8900	4526.3120	3394.7340	2715.7872	2263.1560
78	6084	4778.3736	232.2820	11614.1000	9291.2800	6968.4600	5807.0500	4645.6400	3484.2300	2787.3840	2322.8200
79	6241	4901.6814	238.3093	11915.4650	9532.3720	7149.2790	5957.7325	4766.1860	3574.6395	2859.7116	2383.0930
80	6400	5026.5600	244.3465	12217.3250	9773.8600	7330.3950	6108.6625	4886.9300	3665.1975	2932.1580	2443.4650
81	6561	5153.0094	250.4933	12524.6650	10019.7320	7514.7990	6262.3325	5009.8660	3757.3995	3005.9196	2504.9330
82	6724	5281.0296	256.7166	12835.8300	10268.6640	7701.4980	6417.9150	5134.3320	3850.7490	3080.5992	2567.1660
83	6889	5410.6206	263.0162	13150.8100	10520.6480	7890.4860	6575.4050	5260.3240	3945.2430	3156.1944	2630.1620
84	7056	5541.7824	269.3925	13469.6250	10775.7000	8081.7750	6734.8125	5387.8500	4040.8875	3232.7100	2693.9250
85	7225	5674.5150	275.8444	13792.2200	11033.7760	8275.3320	6896.1100	5516.8880	4137.6665	3310.1328	2758.4440
86	7396	5808.8184	282.3730	14118.6500	11294.9200	8471.1900	7059.3250	5647.4600	4235.5950	3388.4760	2823.7300
87	7569	5944.6926	288.9779	14448.8950	11559.1160	8669.3370	7224.4475	5779.5580	4334.6685	3467.7348	2889.7790
88	7744	6082.1376	295.6593	14782.9650	11826.3720	8869.7790	7391.4825	5913.1860	4434.8895	3547.9116	2956.5930
89	7921	6221.1534	302.4171	15120.8550	12096.6840	9072.5130	7560.4275	6048.3420	4536.2565	3629.0052	3024.1710
90	8100	6361.7400	309.2512	15462.5600	12370.0480	9277.5360	7731.2800	6185.0240	4638.7680	3711.0144	3092.5120
91	8281	6503.8974	316.1616	15808.0800	12646.4640	9484.8480	7904.0400	6323.2320	4742.4240	3793.9392	3161.6160
92	8464	6647.6256	323.1483	16157.4150	12925.9320	9694.4490	8078.7075	6462.9660	4847.2245	3877.7796	3231.4830
93	8649	6792.9246	330.2114	16510.5700	13208.4560	9906.3420	8255.2850	6604.2280	4953.1710	3962.5368	3302.1140
94	8836	6939.7944	337.3510	16867.5500	13494.0400	10120.5300	8433.7750	6747.0200	5060.2650	4048.2120	3373.5100
95	9025	7088.2350	344.5669	17228.3450	13782.6760	10337.0070	8614.1725	6891.3380	5168.5035	4134.8028	3445.6690
96	9216	7238.2464	351.8595	17592.9750	14074.3800	10555.7850	8796.4875	7037.1900	5277.8925	4222.3140	3518.5950
97	9409	7389.8286	359.3944	17969.7200	14375.7760	10781.8320	8984.8600	7187.8880	5390.9160	4312.7328	3593.9440
98	9604	7542.9816	366.6842	18334.2100	14667.3680	11000.5260	9167.1050	7333.6840	5555.2630	4400.2104	3666.8420
99	9801	7697.7054	374.1938	18709.6900	14967.7520	11225.8140	9354.3450	7483.8760	5612.9070	4490.3256	3741.9380
100	10000	7854.0000	381.7915	19089.5750	15271.6600	11453.7450	9544.7875	7635.8300	5726.8725	4581.4980	3817.9150

TABLE V. of the Powers of Steam Engines working at the Rate of 9lbs. Avoirdupoiſe, upon every Circular Inch, or 11.45lb. upon every Square Incl of the Steam Piſton applicable to Blowing Machinery; and the Areas and Diameters of Blowing Cylinders requiſite to raiſe Air of various Den ſities from 1½lb. to 4lbs. upon each Circular Inch, or from 1.90lb. to 5.092lbs. Avoirdupoiſe, upon each Square Inch of the Air receiver.

Diameters of Steam Cylin.	Areas of Do.	Power of the Engine in Pounds.	Blast 1½lb. per Cir. Inch, or 1.90lb. per Square Inch.		Blast 1⅔lb. per Cir. Inch, or 2.12lb. per Square Inch.		Blast 2lb. per Cir. Inch, or 2.54lb. per Square Inch.		Blast 2¼lb. per Cir. Inch, or 2.86lb. per Square Inch.		Blast 2½lb. per Cir. Inch, or 3.18lb. per Square Inch.		Blast 2¾lb. per Cir. Inch, or 3.50lb. per Square Inch.		Blast 3lb. per Cir. Inch, or 3.81lb. per Square Inch.		Blast 3¼lb. per Cir. Inch, or 4.13lb. per Square Inch.		Blast 3½lb. per Cir. Inch, or 4.45lb. per Square Inch.		Blast 3¾lb. per Cir. Inch, or 4.77lb. per Square Inch.		Blast 4lb. per Cir. Inch, or 5.09lb. per Square Inch.	
			Area of blowing Cylinder.	Diameter of Ditto.	Area of blowing Cylinder.	Diameter of Ditto.	Area of blowing Cylinder.	Diameter of Ditto.	Area of blowing Cylinder.	Diameter of Ditto.	Area of blowing Cylinder.	Diameter of Ditto.	Area of blowing Cylinder.	Diameter of Ditto.	Area of blowing Cylinder.	Diameter of Ditto.	Area of blowing Cylinder.	Diameter of Ditto.	Area of blowing Cylinder.	Diameter of Ditto.	Area of blowing Cylinder.	Diameter of Ditto.	Area of blowing Cylinder.	Diameter of Ditto.
20	400	3600	2400	49	2057	45½	1800	42½	1600	40	1440	37½	1309	36	1200	34¾	1107	33¼	1028	32	960	31	900	30
21	441	3969	2646	51½	2268	47½	1984	44½	1764	42	1587	39½	1443	38	1323	36½	1221	35	1134	33½	1058	32½	992	31½
22	484	4356	2904	54	2489	49¾	2178	46½	1936	44	1742	41¾	1584	39¾	1452	38	1340	36½	1244	35	1161	34	1089	33
23	529	4761	3174	56½	2720	52	2380	48¾	2116	46	1904	43½	1731	41½	1587	39½	1464	38¼	1360	36¾	1269	35½	1190	34½
24	576	5184	3456	59	2962	54½	2592	50¾	2304	48	2073	45½	1885	43½	1728	41½	1593	39¾	1480	38½	1382	37	1296	36
25	625	5625	3750	61½	3214	56¾	2812	53	2500	50	2250	47½	2045	45¼	1875	43¼	1730	41½	1607	40	1500	38½	1406	37½
26	676	6084	4056	64	3476	59	3042	55	2704	52	2433	49¼	2212	47	2028	45	1872	43¼	1738	41½	1622	40	1521	39
27	729	6561	4374	66½	3749	61	3280	57¼	2916	54	2620	51	2385	48¾	2187	46¾	2018	45	1874	43¼	1749	41½	1640	40½
28	784	7056	4704	68½	4032	63½	3528	59½	3136	56	2822	53	2565	50½	2352	48½	2171	46½	2016	45	1888	43¼	1764	42
29	841	7569	5046	71	4325	65¾	3784	61½	3364	58	3027	55	2752	52½	2523	50¼	2322	48¼	2162	46½	2018	45	1892	43½
30	900	8100	5400	73½	4628	68	4050	63½	3600	60	3240	57	2945	54¼	2700	52	2402	50	2314	48	2160	46½	2025	45
31	961	8649	5766	76	4922	70¼	4324	65¾	3844	62	3459	58¾	3145	56	2883	53¾	2661	51½	2471	49¾	2306	48	2162	46½
32	1024	9216	6140	78½	5266	72½	4608	68	4096	64	3686	60½	3351	58	3072	55½	2835	53¼	2633	51¼	2457	49½	2304	48
33	1089	9801	6534	81	5600	74¾	4900	70	4356	66	3920	62½	3564	59¾	3267	57¼	3016	55	2802	53	2613	51	2450	49½
34	1156	10404	6936	83¼	5945	77	5202	72	4624	68	4161	64½	3783	61½	3468	59	3201	56¾	2972	54½	2774	52¾	2601	51
35	1225	11025	7350	85½	6300	79½	5512	74¼	4900	70	4410	66½	4009	63¼	3675	60¾	3392	58¼	3150	56	2940	54¼	2756	52½
36	1296	11664	7776	89	6665	81¾	5832	76¼	5184	72	4669	68¼	4241	65	3888	62½	3588	59¾	3332	57¾	3110	56	2916	54
37	1369	12321	8214	90½	7040	84	6160	78½	5476	74	4928	70	4480	67	4107	64	3791	61½	3520	59½	3285	57½	3080	55½
38	1444	12996	8664	93	7426	86¼	6498	80½	5776	76	5198	72	4725	68¾	4332	65¾	3998	63	3713	61	3465	59	3249	57
39	1521	13689	9126	95½	7822	88½	6844	82¾	6084	78	5479	74	4977	70½	4563	67½	4212	65	3911	62½	3650	60½	3422	58½
40	1600	14400	9600	98	8228	90¾	7200	85	6400	80	5760	76	5236	72¼	4800	69¼	4430	66¾	4114	64	3840	62	3600	60
41	1681	15129	10086	100½	8645	93	7564	87	6724	82	6051	78	5501	74¼	5043	71	4655	68¼	4322	65½	4034	63½	3782	61½
42	1764	15876	10584	103	9072	95¼	7938	89	7056	84	6350	79¾	5773	76	5292	72¾	4884	69¾	4536	67¼	4231	65	3969	63
43	1849	16641	11094	105½	9509	97½	8320	91¼	7396	86	6656	81½	6051	78	5547	74½	5120	71½	4754	69	4437	66½	4160	64½
44	1936	17424	11616	107¾	9956	99¾	8712	93½	7744	88	6969	83½	6336	79¾	5808	76¼	5361	73¼	4978	70½	4646	68	4316	66
45	2025	18225	12150	110¼	10414	102	9112	95½	8100	90	7290	85¼	6620	81½	6075	78	5607	75	5207	72	4860	69½	4556	67½
46	2116	19044	12696	112½	10882	104¼	9522	97	8464	92	7617	87¼	6925	83¼	6348	79½	5859	76½	5441	73½	5078	71¼	4761	69
47	2209	19881	13254	115	11360	106½	9940	99¾	8836	94	7952	89¼	7229	85	6627	81¼	6117	78¼	5680	75¼	5301	73	4970	70½
48	2304	20736	13824	117½	11849	108¾	10368	101½	9216	96	8294	91	7540	87	6912	83	6380	80	5923	77	5529	74½	5184	72
49	2401	21609	14486	120	12348	111¼	10804	104	9604	98	8643	93	7857	88¾	7203	84¾	6648	81¾	6174	78½	5762	76	5402	73½
50	2500	22500	15000	122½	12857	113½	11250	106	10000	100	9000	95	8181	90½	7500	86½	6923	83¼	6428	80	6000	77½	5625	75
51	2601	23409	15606	125	13376	115¾	11704	108¼	10404	102	9360	96¾	8516	92¼	7803	88¼	7202	85	6688	81¾	6242	79	5852	76½
52	2704	24336	16224	127½	13906	118	12168	110¼	10816	104	9734	98½	8849	94	8112	90	7488	86½	6953	83½	6489	80½	6084	78
53	2809	25281	16854	129¾	14446	120¼	12640	112½	11236	106	10112	100½	9193	95¾	8427	91¾	7778	88¼	7223	85	6741	82	6320	79½
54	2916	26244	17496	132¼	14996	122½	13122	114½	11664	108	10497	102½	9543	97½	8748	93½	8075	90	7498	86½	6998	83¾	6561	81
55	3025	27225	18150	134½	15557	125¾	13612	116¼	12100	110	10890	104½	9900	99½	9075	95¼	8370	91¾	7778	88¼	7260	85½	6806	82½
56	3136	28224	18816	137	16128	127	14112	118¾	12544	112	11289	106¼	10263	101¼	9408	97	8684	93¼	8064	89¾	7526	87	7056	84
57	3249	29241	19494	139½	16709	129¼	14620	121	12996	114	11696	108¼	10633	103	9747	98¾	8997	94¾	8354	91½	7797	88½	7310	85½
58	3364	30276	20184	142	17300	131½	15138	123	13456	116	12110	110	11009	105	10092	100½	9315	96½	8650	93	8073	90	7569	87
59	3481	31329	20886	144½	17902	133¾	15664	125¼	13924	118	12531	112	11392	106¾	10443	102¼	9637	98¼	8951	94½	8357	91½	7832	88½
60	3600	32400	21600	147	18514	136	16200	127¼	14400	120	12960	114	11781	108½	10800	104	9969	99¾	9257	96¼	8640	93	8100	90
61	3721	33489	22326	149½	19136	138¼	16744	129½	14884	122	13395	115¾	12177	110½	11163	105¾	10304	101½	9568	97¾	8930	94½	8372	91½
62	3844	34596	23064	152	19769	140½	17298	131½	15376	124	13838	117½	12578	112½	11532	107½	10644	103¼	9884	99½	9225	96	8649	93
63	3969	35721	23814	154½	20412	142¾	17860	133¾	15876	126	14283	129½	12989	114	11907	109¼	10991	104¾	10206	101	9525	97½	8930	94½
64	4096	36864	24576	156¾	21065	145	18432	135¾	16384	128	14745	121½	13405	115¾	12288	111	11342	106½	10532	102½	9830	99	9216	96
65	4225	38025	25350	158½	21728	147½	19012	138	16900	130	15210	123½	13827	117½	12675	112½	11698	108	10864	104¼	10140	100½	9506	97½
66	4356	39204	26136	161	22402	149¾	19602	140	17424	132	15681	125¼	14256	119½	13068	114¼	12062	109¾	11201	106	10454	102	9801	99
67	4489	40401	26934	163¾	23086	151¾	20200	142¼	17956	134	16160	127¼	14691	121	13467	116	12431	111½	11543	107½	10773	103½	10100	100½
68	4624	41616	27744	166	23777	154	20808	144¼	18496	136	16646	129	15133	123	13872	117¾	12804	113¼	11890	109	11097	105	10404	102
69	4761	42849	28566	169	24485	156½	21424	146¼	19044	138	17139	130¾	15578	124¾	14283	119½	13184	114¾	12242	110¾	11426	106¾	10712	103½
70	4900	44100	29400	172¾	25200	158¾	22050	148½	19600	140	17640	132¾	16036	126¾	14700	121¼	13569	116½	12600	112¼	11760	108¼	11025	105

TABLE I. of the Powers of Steam Engines working at the Rate of 5 lbs. Avoirdupoise upon every Circular Inch, or 6.3656 lb. upon every Square Inch of the Steam Piston applicable to Blowing Machinery; and the Areas and Diameters of Blowing Cylinders requisite to raise Air of various Densities from 1½ lb. to 4 lbs. upon each Circular Inch, or from 1.90 lb. to 5.092 lbs. Avoirdupoise upon each Square Inch of the Air Receiver.

Diameters of Steam Cylind.	Area of Ditto.	Power of the Engine in Pounds	Blast 1½ lb. per Circular Inch, or 1.90 lb. per Square Inch.		Blast 1¾ per Circular Inch, or 2.22 lb. per Square Inch		Blast 2 lb. per Circular Inch, or 2.54 lb. per Square Inch.		Blast 2¼ lb. per Circular Inch, or 2.86 lb. per Square Inch.		Blast 2½ lb. per Circular Inch, or 3.18 lb. per Square Inch.		Blast 2¾ lb. per Circular Inch, or 3.49 lb. per Square Inch.		Blast 3 lb. per Circular Inch, or 3.81 lb. per Square Inch.		Blast 3¼ lb. per Circular Inch, or 4.13 lb. per Square Inch.		Blast 3½ lb. per Circular Inch, or 4.45 lb. per Square Inch.		Blast 3¾ lb. per Circular Inch, or 4.77 lb. per Square Inch.		Blast 4 lb. per Circular Inch, or 5.09 lb. per Square Inch.	
			Area of blowing Cylinder.	Diam. of Ditto.	Area of blowing Cylinder.	Diameter of Ditto.	Area of blowing Cylinder.	Diameter of Ditto.	Area of blowing Cylinder.	Diameter of Ditto.	Area of blowing Cylind.	Diam. of Ditto.	Area of blowing Cylind.	Diam. of Ditto.	Area of blowing Cylind.	Diam. of Ditto.	Area of blowing Cylind.	Diam. of Ditto.	Area of blowing Cylind.	Diam. of Ditto	Area of blowing Cylind.	Diam. of Ditto	Area of blowing Cylind.	Diam. of Ditto
20	400	2000	1333	36½	1142	34	1000	32	888	29½	800	28¾	727	27	666	26	615	24¾	571	24	533	23	500	22¾
21	441	2205	1470	38¼	1260	35½	1102	33½	980	31¼	882	29½	801	28¼	735	27¼	678	26	630	25	588	24	551	23¾
22	484	2420	1613	40	1383	37¼	1210	35	1075	33	962	31	880	29½	806	28½	744	27¼	691	26¼	645	25¼	605	24½
23	529	2645	1763	42	1511	39	1322	36½	1175	34¼	1058	32¼	961	31	881	29¾	813	28½	755	27½	705	26½	661	25¼
24	576	2880	1920	44	1645	40½	1440	38	1280	35¾	1152	34	1047	32¼	960	31	886	29¾	822	28½	768	27¾	720	27
25	625	3125	2083	45¾	1785	42¼	1562	39½	1388	37¼	1250	35¼	1136	33¾	1041	32¼	961	31	892	29¾	833	29	781	28
26	676	3380	2253	47½	1931	44	1690	41	1502	38¾	1352	36¾	1229	35	1126	33½	1040	32¼	965	31	901	30	845	29
27	729	3645	2430	49¼	2082	45½	1822	42½	1620	40¼	1458	38	1325	36½	1215	33¾	1121	33½	1041	32¼	972	31	911	30¼
28	784	3920	2613	51	2240	47¼	1960	44	1742	41¼	1568	39½	1425	37¼	1306	36	1206	34¾	1120	33½	1045	32¾	980	31½
29	841	4205	2803	53	2402	49	2102	45½	1868	43¼	1682	41	1529	39	1401	37¼	1293	36	1201	34¼	1121	33½	1051	32½
30	900	4500	3000	54¾	2571	50¾	2250	47¼	2000	44¾	1800	42¼	1636	40½	1500	38¾	1384	37¼	1285	36	1200	34¾	1125	33½
31	961	4805	3203	56½	2745	52½	2402	49	2135	46¼	1922	44	1747	41¼	1601	40	1478	38½	1371	37¼	1281	36	1201	34¾
32	1024	5120	3413	58½	2925	54	2560	50½	2275	47¾	2048	45¼	1861	43	1706	41¼	1575	39¾	1462	38¼	1365	37	1280	35¾
33	1089	5445	3630	60¼	3111	55¼	2722	52	2420	49¼	2178	46¾	1980	44½	1815	42½	1675	41	1554	39½	1452	38	1361	37
34	1156	5780	3853	62	3302	57½	2890	53¾	2568	50¾	2312	48¼	2101	46	1926	43¾	1770	42¼	1651	40½	1541	39¼	1445	38
35	1225	6125	4083	64	3500	59¼	3062	55¼	2722	52¼	2450	49½	2227	47¼	2041	45	1884	43½	1748	41¾	1633	40½	1531	39¼
36	1296	6480	4320	66	3702	61	3240	57	2880	53¾	2592	50¾	2356	48½	2160	46½	1993	44¾	1851	43	1728	41¼	1620	40¼
37	1369	6845	4563	67¾	3911	62½	3422	58½	3042	55¼	2738	52¼	2489	49¾	2281	47¾	2106	46	1954	44¼	1825	42¾	1711	41½
38	1444	7220	4800	69¼	4125	64¼	3610	60	3208	56½	2888	53¾	2625	51¼	2406	49	2221	47¼	2062	45½	1925	44	1805	42½
39	1521	7605	5070	71	4345	66	3802	61¾	3380	58	3042	55	2765	52½	2535	50¼	2338	48½	2172	46¾	2028	45	1901	43¾
40	1600	8000	5333	73	4571	67¾	4000	63¾	3555	59½	3200	56¼	2909	54	2666	51½	2461	49¾	2285	47¾	2033	46¼	2000	44¾
41	1681	8405	5603	75	4802	69½	4202	64¾	3735	61	3362	58	3056	55¾	2801	53	2586	51	2400	49	2241	47½	2101	45¾
42	1764	8820	5880	76¾	5040	71	4410	66¼	3920	62½	3528	59½	3207	56½	2940	54¼	2713	52¼	2520	50¼	2352	48½	2205	47
43	1849	9245	6230	79	5340	72¾	4622	68	4108	64	3698	60¾	3361	58	3081	55½	2844	53½	2656	51½	2465	49¾	2311	48
44	1936	9680	6453	80½	5531	74½	4840	69½	4302	65½	3872	62¾	3520	59¾	3226	57¾	2978	54¾	2765	52½	2581	50¾	2420	49¾
45	2025	10125	6750	82	5784	76	5062	71	4500	67	4050	63¾	3681	60¾	3375	58	3115	56	2891	53¾	2700	52	2531	50¾
46	2116	10580	7053	84	6004	77¾	5290	72¾	4704	68½	4232	65	3847	62	3526	59¾	3255	57	3022	55	2821	53	2645	51½
47	2209	11045	7363	85¾	6311	79½	5522	74¼	4891	70	4418	66½	4016	63½	3681	60½	3398	58¼	3155	56¼	2945	54¼	2761	52½
48	2304	11520	7680	87½	6582	81	5760	75¾	5120	71½	4608	67¾	4189	64¾	3840	62	3544	59½	3291	57½	3072	55½	2880	53¾
49	2401	12005	8003	89¼	6857	82¾	6002	77½	5335	73	4802	69½	4365	66	4001	63½	3693	60¾	3428	58½	3201	56¼	3001	54¾
50	2500	12500	8333	91¼	7142	84½	6250	79	5555	74½	5000	71¼	4545	67½	4166	64¾	3846	62	3571	59¾	3333	58	3125	56
51	2601	13005	8666	93	7431	86¼	6502	80½	5780	76	5202	72¾	4729	68¾	4335	66	4001	63¼	3714	61	3468	59	3251	57
52	2704	13520	9013	95	7725	88	6760	82¼	6008	77½	5408	73½	4916	70	4506	67¼	4160	64½	3862	62¼	3605	60	3380	58
53	2809	14045	9363	96¾	8025	89¾	7022	83¾	6242	79	5618	75	5107	71½	4681	68½	4321	65¾	4012	63½	3745	61¼	3511	59¾
54	2916	14580	9720	98½	8831	91½	7290	85½	6480	80½	5832	76¼	5301	72¾	4860	69¾	4486	67	4165	64¾	3888	62½	3645	60¼
55	3025	15125	10083	100½	8642	93	7562	87	6722	82	6050	78¾	5500	74¾	5041	71	4653	68¾	4321	65¾	4033	63½	3781	61½
56	3136	15680	10453	102½	8960	94¾	7840	88½	6968	83½	6272	79¾	5701	75½	5226	72¼	4824	69½	4480	67	4181	64¾	3920	62½
57	3249	16245	10830	104	9282	96½	8122	90	7220	85	6498	80¾	5907	76¾	5415	73¾	4996	70¾	4640	68¼	4332	65¾	4061	63¾
58	3364	16820	11213	106	9611	98	8410	91¾	7475	86½	6728	82	6112	78¼	5606	75	5175	72	4805	69¾	4481	67	4205	64¾
59	3481	17405	11603	107¾	9945	99¾	8702	93¼	7735	88	6962	83½	6329	79½	5801	76¼	5355	73¾	4971	70½	4641	68	4351	66
60	3600	18000	12000	109¾	10285	101½	9000	95	8000	89½	7200	84¾	6545	81	6000	77½	5538	74½	5142	71¾	4800	69¾	4500	67
61	3721	18605	12403	111½	10628	103¼	9302	96½	8268	91	7460	86¼	6765	82¼	6201	78¾	5724	75¾	5315	73	4961	70½	4650	68¼
62	3844	19220	12813	112¾	10982	104¾	9610	98	8542	92½	7688	87¼	6989	83½	6406	80	5913	77	5491	74	5125	71½	4805	69½
63	3969	19845	13230	115	11340	106½	9922	99½	8820	94	7938	89	7216	85	6615	81¼	6106	78¼	5697	75¼	5292	72¾	4961	70½
64	4096	20480	13653	117	11702	108¾	10240	101¼	9102	95½	8192	90¼	7447	86¼	6826	82½	6301	79½	5851	76½	5461	74	5120	71½
65	4225	21125	14083	118¾	12071	110	10562	102¾	9388	97	8482	91¼	7681	87¾	7041	84	6500	80¾	6035	77¾	5633	75	5281	72½
66	4356	21780	14520	120½	12445	111¾	10890	104½	9680	98½	8712	93¼	7920	89	7260	85¼	6701	81¾	6222	79	5808	76¼	5445	73¾
67	4489	22445	14963	122½	12825	113½	11222	106	9975	100	8978	94¼	8161	90¼	7481	86½	6906	83	6412	80	5985	77½	5611	75
68	4624	23120	15413	124¼	13211	115	11560	107½	10275	101½	9248	96	8407	91¾	7706	87¾	7113	84¾	6605	81¼	6165	78¾	5780	76
69	4761	23805	15870	126	13602	116¾	11902	109	10580	103	9522	97½	8656	93	7935	89	7326	85½	6801	82½	6348	80	5951	77
70	4900	4500	16333	128	14000	118¾	12250	110¼	10888	104½	9800	99	8909	94½	8166	90½	7538	86¾	7000	82¾	6553	81¼	6125	78¼

TABLE II. of the Powers of Steam Engines working at the Rate of 6 lbs. Avoirdupoise upon every Circular Inch, or 7.639 lb. upon every Square Inch of the Steam Piston applicable to Blowing Machinery; and the Areas and Diameters of Blowing Cylinders requisite to raise Air of various Densities from 1½ lb. to 4 lbs. upon each Circular Inch, or from 1.90 lb. to 5.092 lbs. Avoirdupoise upon each Square Inch of the Air Receiver.

Diameter of Steam Cylind.	Area of Ditto.	Power of the Engine in Pounds.	Blast 1½ lb. per Circular Inch, or 1.90 lb. per Square Inch.		Blast 1¾ lb. per Circular Inch, or 2.22 lb. per Square Inch		Blast 2 lb. per Circular Inch, or 2.54 lb per square Inch.		Blast 2¼ lb. per Circular Inch, or 2.86 lb. per Square Inch.		Blast 2½ lb. per Circular Inch, or 3.18 lb. per Square Inch.		Blast 2¾ lb. per Circular Inch, or 3.41 lb. per Square Inch.		Blast 3 lb. per Cir. Inch, or 3.81 lb. per Square Inch.		Blast 3¼ lb. per Cir. Inch, or 4.13 lb. per Square Inch		Blast 3½ lb. per Cir. Inch, or 4.45 lb. per Square Inch.		Blast 3¾ lb per Cir. Inch, or 4.77 lb. per Square Inch		Blast 4 lb. per Circular Inch, or 5.09 lb. per Square Inch.	
			Area of blowing Cylind	Diam. of Ditto.	Area of blowing Cylinder	Diameter of Ditto	Area of blowing Cylinder	Diameter of Ditto	Area of blowing Cylind.	Diameter of Ditto.	Area of blowing Cylind.	Diameter of Ditto.	Area of blowing Cylind.	Diameter of Ditto.	Area of blowing Cylind.	Diam. of Ditto	Area of blowing Cylind	Diam. of Ditto	Area of blowing Cylind	Diam. of Ditto	Area of blowing Cylind.	Diam. of Ditto	Area of blowing Cylind	Diam. of Ditto.
20	400	2400	1600	40	1371	37	1200	34¾	1066	32¾	960	31	872	29½	800	28¼	788	27¼	685	26¼	640	25½	600	24¾
21	441	2646	176	42	1512	38¾	1323	36½	1176	34¼	1058	32½	962	31	882	29½	814	28½	756	27½	705	26½	661	25¼
22	484	2904	1936	44	1659	40½	1452	38	1290	36	1161	34	1056	32½	968	31	803	30	829	28¾	774	27¾	726	27
23	529	3174	2116	46	1813	42¼	1587	39¾	1410	37½	1269	35½	1154	34	1058	32½	976	31¼	909	30	846	29	793	28
24	576	3456	2304	48	1974	44½	1728	41½	1536	39	1382	37	1256	35½	1152	34	1063	32¼	987	31¼	921	30½	864	29¼
25	625	3750	2500	50	2142	46¼	1875	43¼	1666	40¾	1500	38½	1363	37	1250	35½	1153	34	1071	32½	1000	31½	937	30½
26	676	4056	2704	52	2317	48	2028	45	1802	42½	1622	40	1475	38½	1352	37	1248	35¼	1159	34	1081	32¾	1014	31¾
27	729	4374	2916	54	2499	50	2187	46¾	1944	44	1749	41¾	1590	40	1458	38¼	1345	36¼	1249	35¼	1166	34	1093	33
28	784	4704	3136	56	2688	51¾	2352	48½	2090	45½	1880	43¼	1710	41½	1568	39½	1447	38	1344	36½	1254	35¼	1176	34
29	841	5046	3364	58	2883	53½	2523	50¼	2242	47¼	2018	45	1834	43	1682	41	1552	39¼	1441	38	1345	36½	1261	35½
30	900	5400	3600	60	3085	55½	2700	52	2400	49	2160	46½	1963	44½	1800	42½	1661	40¾	1542	39¼	1440	37¾	1350	36¾
31	961	5766	3844	62	3289	57¼	2883	53¾	2562	50½	2306	48	2096	46	1922	44	1774	42	1645	40½	1537	39	1441	38
32	1024	6144	4096	64	3510	59	3072	55½	2730	52¼	2457	49½	2234	47½	2048	45¼	1819	43½	1755	41¾	1638	40¼	1536	39¼
33	1089	6534	4356	66	3733	61	3267	57¼	2904	54	2613	51	2376	49	2178	46¾	2010	45	1866	43¼	1742	41½	1633	40½
34	1156	6936	4624	68	3963	63	3468	59¾	3082	55½	2774	52½	2522	50½	2312	48	2134	46¼	1981	44½	1849	43	1734	41¾
35	1225	7350	4900	70	4200	65	3675	60½	3266	57¼	2940	54	2672	51¾	2450	49½	2261	47½	2100	45¾	1960	44¼	1837	43
36	1296	7776	5184	72	4443	66¾	3888	62¼	3456	59	3110	55½	2827	53¼	2592	51	2392	49	2221	47	2073	45½	1944	44¼
37	1369	8214	5476	74	4693	68½	4107	64	3650	60½	3285	57	2986	54¾	2738	52½	2527	50¼	2346	48¼	2190	46¾	2053	45¼
38	1444	8664	5776	76	4950	70¼	4332	65¾	3850	62	3465	58½	3150	56	2888	53¾	2662	51½	2475	49¾	2310	48	2166	46¾
39	1521	9126	6084	78	5214	72¼	4563	67½	4056	63¾	3650	60¼	3314	57½	3042	55	2808	53	2607	51¼	2433	49¼	2281	48
40	1600	9600	6400	80	5485	74	4800	69¼	4266	65½	3840	62	3490	59	3200	56½	2953	54½	2742	52¼	2560	50½	2400	49
41	1681	10086	6724	82	5763	76	5043	71	4482	67	4034	63½	3667	60½	3362	58	3103	55¾	2881	53¾	2689	51¾	2521	50¼
42	1764	10584	7056	84	6048	77¾	5292	72¾	4704	68½	4233	65	3848	62	3528	59½	3256	57	3024	55	2822	53	2646	51½
43	1849	11094	7396	86	6339	79½	5547	74½	4961	70¼	4485	66½	4034	62½	3698	60¾	3413	58½	3169	56¼	2958	54½	2773	52½
44	1936	11616	7744	88	6637	81½	5808	76¼	5162	72	4646	68	4224	64¼	3872	62	3574	60	3318	57½	3097	55½	2904	53¾
45	2025	12150	8100	90	6942	83¼	6075	78	5400	73½	4860	69½	4418	66½	4050	63½	3738	61¼	3471	59	3240	56¼	3037	55
46	2116	12696	8464	92	7254	85	6348	79¾	5642	75	5078	71¼	4616	68	4232	65	3906	62½	3627	60¼	3385	58	3176	56¼
47	2209	13254	8836	94	7573	87	6627	81¾	5890	76¾	5301	73	4819	69½	4418	66½	4078	64	3786	61½	3534	59½	3313	57½
48	2304	13824	9216	96	7899	88¾	6912	83¼	6144	78½	5529	74½	5026	71	4608	68	4253	65¼	3949	62¾	3686	60½	3456	58¾
49	2401	14406	9364	98	8232	90¾	7203	84¾	6402	80	5762	76	5238	72½	4802	69½	4432	66¼	4116	64	3841	61¾	3601	59¾
50	2500	15000	10000	100	8571	92½	7500	86½	6666	81½	6000	77½	5454	74	5000	70¾	4613	68	4285	65½	4000	63	3750	61
51	2601	15606	10404	102	8917	94½	7803	88½	6936	83¼	6242	79	5675	75½	5202	72	4801	69¼	4458	66½	4161	64½	3901	62¼
52	2704	16224	10816	104	9270	96¼	8112	90	7210	85	6489	80½	5899	77	5408	73½	4992	70¾	4635	67¾	4326	65¼	4056	63½
53	2809	16854	11236	106	9630	98¼	8427	91¾	7490	86½	6741	82	6128	78½	5618	75	5185	72	4815	69¼	4494	67	4213	64¾
54	2916	17496	11664	108	9997	100	8748	93¾	7776	88	6996	83¾	6362	79¾	5832	76½	5383	73½	4998	70½	4665	68¼	4374	66
55	3025	18150	12100	110	10371	101¾	9075	95½	8066	89¾	7260	85¼	6600	81¼	6050	77¾	5584	74¾	5185	72	4840	69½	4537	67¼
56	3136	18816	12544	112	10752	103¾	9408	97	8362	91½	7526	86¾	6842	82¾	6272	79¼	5789	76	5378	73¼	5017	70¾	4704	68¾
57	3249	19494	12996	114	11139	105½	9747	98¾	8664	93	7797	88¼	7088	84	6428	80½	5998	77½	5569	74½	5198	72	4873	69¾
58	3364	20184	13456	116	11533	107½	10092	100½	8970	94½	8073	89¾	7339	85½	6728	82	6210	78¾	5765	75¾	5382	73¼	5046	71
59	3481	20886	13924	118	11935	109¼	10443	102¼	9280	96¼	8354	91½	7594	87	6962	83½	6426	80	5967	77¼	5569	74½	5221	72¼
60	3600	21600	14400	120	12342	111	10800	104	9600	98	8640	93	7854	88½	7200	85	6646	81½	6171	78½	5760	75¾	5400	73½
61	3721	22326	14884	122	12754	113	11163	105¾	9922	99¾	8930	94½	8118	90	7442	86½	6860	83	6378	79¾	5953	77	5581	74¾
62	3844	23064	15376	124	13179	114¾	11532	107½	10250	101¼	9225	96	8386	91½	7688	87¼	7096	84¼	6589	81	6150	78¼	5766	76
63	3969	23814	15875	126	13608	116½	11907	109¼	10584	103	9525	97¼	8659	93	7938	89	7327	85½	6804	82¼	6350	79½	5953	77¼
64	4096	24576	16384	128	14043	118½	12288	110¾	10922	104¼	9830	99	8936	94½	8192	90½	7561	87	7021	83½	6553	80¾	6144	78¼
65	4225	25350	16900	130	14485	120¼	12675	112½	11266	106¼	10140	100¾	9218	96	8450	92	7800	88½	7242	84¼	6760	82	6337	79¼
66	4356	26136	17424	132	14934	122¼	13068	114¼	11616	107¾	10454	102¼	9504	97½	8712	93½	8041	89¾	7467	86¼	6969	83½	6534	81
67	4489	26934	17956	134	15390	124	13467	116	11970	109½	10773	103¾	9794	99	8978	94¾	8287	91	7695	87¾	7182	84½	6733	82¼
68	4624	27744	18496	136	15853	126	13872	117¾	12230	111	11097	105¼	10088	100½	9248	96¼	8536	92¼	7924	89	7398	85¾	6936	83¼
69	4761	28566	19044	138	16323	127¾	14283	119½	12693	112½	11426	107	10387	102	9522	97¾	8789	93¾	8161	90¼	7617	87¼	7141	84½
70	4900	29400	19600	140	16800	129½	14700	121¼	13066	114¼	11760	108½	10690	103½	9800	99¼	9046	95	8400	91½	7840	88½	7350	85¼

TABLE III. of the Powers of Steam Engines working at the Rate of 7lbs. Avoirdupoise upon every Circular Inch, or 8.91lb. upon every Square Inch of the Steam Piston, applicable to Blowing Machinery; and the Areas and Diameters of Blowing Cylinders, requisite to raise Air of various densities from 1½lb to 4lbs. upon each Circular Inch, or from 1.90lb. to 5.092lbs. Avoirdupoise upon each Square Inch of the Air Receiver.

Steam Cylin.	Area of Do.	Power of the Engine in Pounds.	Blast 1½lb. per Cir. Inch, or 1.91lb. per Square Inch.		Blast 1¾lb. per Cir. Inch, or 2.22lb. per Square Inch.		Blast 2lb. per Cir. Inch, or 2.54lb. per Square Inch.		Blast 2¼lb. per Cir. Inch, or 2.86lb. per Square Inch.		Blast 2½lb. per Cir. Inch, or 3.18lb. per Square Inch.		Blast 2¾lb. per Cir. Inch, or 3.41lb. per Square Inch.		Blast 3lb. per Cir. Inch, or 3.81lb. per Square Inch.		Blast 3¼lb. per Cir. Inch, or 4.13lb. per Square Inch.		Blast 3½lb. per Cir. Inch, or 4.45lb. per Square Inch.		Blast 3¾lb. per Cir. Inch, or 4.77lb. per Square Inch.		Blast 4lb. per Cir. Inch, or 5.09lb. per Square Inch.	
			Area of blowing Cylinder.	Diameter of Ditto.	Area of blowing Cylinder.	Diameter of Ditto.	Area of blowing Cylinder.	Diameter of Ditto.	Area of blowing Cylinder.	Diameter of Ditto.	Area of blowing Cylinder.	Diameter of Ditto.	Area of blowing Cylinder.	Diameter of Ditto.	Area of blowing Cylinder.	Diameter of Ditto.	Area of blowing Cylinder.	Diameter of Ditto.	Area of blowing Cylind.	Diam. of Ditto.	Area of blowing Cylind.	Diam of Ditto	Area of blowing Cylind.	Diam. of Ditto.
0	400	2800	1866	43¼	1600	40	1400	37½	1244	35¼	1120	33½	1014	31¾	933	30¼	861	29	800	28¼	746	27¼	700	26½
1	441	3087	2058	45¼	1764	42	1543	39¼	1372	37	1234	35	1122	33½	1029	32	949	30½	882	29½	822	28½	771	27¾
2	484	3388	2258	47½	1936	44	1699	41	1505	38¾	1355	36¾	1232	35	1129	33½	1042	32	968	31	903	30	837	29
3	529	3703	2468	49½	2116	46	1851	43	1645	40½	1481	38½	1346	36½	1234	35	1139	33½	1058	32½	987	31¼	925	30¼
4	576	4032	2688	51¾	2304	48	2016	45	1792	42	1612	40	1466	38¼	1344	36½	1240	35	1152	34	1075	32¾	1008	31½
5	625	4375	2916	54	2500	50	2187	46¾	1944	43½	1750	41¾	1590	40	1458	38	1346	36½	1250	35¼	1166	34	1093	32¾
6	676	4732	3154	56	2704	52	2366	48½	2103	46	1892	43½	1720	41½	1574	39½	1456	38	1350	36¾	1261	35½	1183	34
7	729	5103	3402	58¼	2916	54	2551	50½	2268	47½	2041	45¼	1855	43	1701	41	1570	39½	1458	38	1360	37	1275	35½
8	784	5488	3658	60½	3136	56	2744	52½	2439	49¼	2195	46¾	1995	44½	1829	42¾	1688	41	1568	39½	1463	38¼	1372	36¾
9	841	5887	3924	62½	3364	58	2943	54¼	2616	51½	2354	48½	2104	46	1962	44¼	1811	42½	1682	41	1569	39½	1471	38¼
0	900	6300	4200	64¾	3600	60	3150	56	2800	53	2520	50¼	2290	47½	2100	45¾	1938	44	1800	42½	1680	41	1575	39½
1	961	6727	4484	67	3844	62	3363	58	2989	54½	2690	51¾	2446	49	2242	47¼	2069	45½	1920	44	1793	42¼	1681	41
2	1021	7168	4778	69¼	4096	64	3584	59¾	3185	56¼	2867	53½	2606	50¼	2389	48¾	2205	47	2048	45¼	1911	43¾	1792	42¼
3	1089	7623	5080	71¼	4356	66	3811	61¾	3388	58	3049	55	2772	52½	2541	50½	2345	48½	2178	46½	2032	45	1905	43½
4	1156	8092	5394	73½	4624	68	4046	63¾	3396	59½	3236	56¾	2942	54¼	2697	52	2489	50	2312	48	2157	46½	2023	44¾
5	1225	8575	5716	75½	4900	70	4287	65½	3811	61¾	3430	58½	3118	56	2858	53½	2638	51½	2450	49½	2286	47¾	2143	46¼
6	1296	9072	6048	77¾	5184	72	4536	67¼	4032	63¾	3628	60¼	3299	57½	3024	55	2791	53	2592	51	2419	49¼	2268	47½
7	1349	9583	6388	80	5476	74	4791	69	4259	65¼	3833	62	3484	59	3194	56½	2948	54½	2738	52½	2555	50½	2395	49
8	1444	10108	6738	82	5776	76	5054	71	4491	67	4043	63½	3675	60½	3369	58	3110	56	2888	53¾	2695	52	2527	50¼
9	1521	10647	7098	84¼	6084	78	5323	73	4732	68¾	4258	65¼	3872	62	3549	59½	3276	57¼	3042	55	2839	53¼	2661	51½
0	1600	11200	7466	86½	6400	80	5600	75	4977	70½	4480	67	4072	63½	3733	61	3446	58¾	3200	56½	2986	54¾	2880	52¾
1	1681	11767	7844	88½	6724	82	5883	76¾	5229	72¼	4706	68½	4278	65¼	3922	62½	3620	60¼	3360	58	3137	56	2941	54¼
2	1764	12348	8232	90½	7056	84	6174	78½	5488	74	4939	70¼	4490	67	4116	64	3799	61¾	3528	59½	3292	57½	3087	55½
3	1849	12943	8628	92¾	7396	86	6471	80½	5752	75¾	5177	72	4706	68½	4314	65½	3982	63	3698	60¾	3451	58¾	3235	57
4	1936	13552	9034	95	7744	88	6776	82½	6023	77½	5420	73½	4928	70	4517	67	4169	64½	3872	62½	3613	60	3388	58¼
5	2025	14175	9430	97¼	8100	90	7087	84½	6300	79¼	5670	75¼	5154	71½	4725	68½	4361	66	4050	63¾	3780	61½	3543	59½
6	2116	14812	9874	99½	8464	92	7406	86	6583	81	5924	77	5386	73¼	4937	70	4557	67½	4232	65	3949	62¾	3703	60¾
7	2209	15463	10308	101½	8836	94	7731	88	6872	82¾	6185	78¾	5622	75	5154	71¾	4757	69	4418	66½	4123	64¼	3865	62
8	2304	16128	10752	103¾	9216	96	8064	89¾	7168	84½	6451	80¼	5864	76½	5376	72½	4962	70½	4608	68	4300	65¾	4032	63½
9	2401	16807	11204	106	9604	98	8403	91½	7469	86¼	6722	82	6111	78	5602	74¾	5171	72	4802	69½	4481	67	4201	64¾
0	2500	17500	11666	108	10000	100	8750	93½	7777	88	7000	83¾	6363	79½	5833	76½	5384	73½	5000	70¾	4666	68½	4375	66¼
1	2601	18207	12138	110¼	10404	102	9103	95½	8092	90	7282	85¼	6620	81¼	6069	78	5602	75	5202	72	4855	70	4551	67½
2	2704	18928	12618	112½	10816	104	9464	97¼	8412	91¾	7571	87	6882	83	6309	79½	5824	76½	5408	73½	5047	71½	4782	68¾
3	2809	19663	13108	114½	11236	106	9831	99¼	8739	93½	7865	88¾	7150	84½	6554	81	6050	78	5618	75	5243	73	4915	70
4	2916	20412	13608	116½	11664	108	10206	101	9072	95¼	8164	90¼	7422	86	6804	82½	6280	79¼	5832	76½	5443	74¾	5103	71¾
5	3025	21175	14116	118¾	12102	110	10587	103	9411	97	8470	92	7700	87½	7058	84	6515	80¾	6050	78	5646	75½	5293	72½
6	3136	21952	14634	121	12544	112	10976	104½	9756	98¾	8780	93¾	7982	89	7317	85½	6754	81¼	6272	79¼	5853	76¾	5488	74
7	3249	22743	15162	123¼	12996	114	11371	106½	10108	100½	9097	95¼	8470	90¼	7581	87	6997	83¾	6498	80½	6064	78	5685	75½
8	3364	23548	15698	125½	13456	116	11774	108½	10465	102	9419	97	8562	92½	7849	88½	7245	85	6728	82	6279	79¼	5887	76¾
9	3481	24367	16244	127½	13920	118	12183	110¼	10829	104	9746	98¾	8860	94	8122	90	7497	86½	6962	83½	6497	80½	6091	78
0	3600	25200	16800	129½	14400	120	12600	112¼	11200	105¾	10080	100¼	9163	95¾	8400	91½	7754	88	7200	85	6720	82	6300	79¼
1	3721	26047	17364	131¾	14884	122	13023	114	11573	107½	10418	102	9471	97¼	8682	93	8014	89½	7442	86¼	6945	83¼	6511	80½
2	3844	26908	17938	134	15376	124	13454	116	11959	108¾	10763	103¾	9784	99	8969	94½	8279	91	7688	87½	7175	84¾	6727	82
3	3969	27783	18522	136	15876	126	13891	117¾	12348	111	11113	105¼	10102	100½	9261	96	8548	92½	7938	89	7408	86	6945	83½
4	4096	28672	19114	138¼	16384	128	14336	119¾	12743	113	11488	107	10426	102	9557	97½	8822	94	8192	90½	7645	87¼	7168	84¾
5	4225	29575	19716	140¼	16900	130	14787	121½	13144	114¾	11830	108¾	10754	103½	9858	99	9100	95½	8451	92	7886	88¾	7393	86
6	4356	30492	20328	142¾	17424	132	15246	123½	13552	116½	12196	110¼	11088	105¼	10164	100½	9382	97	8712	93¼	8130	90¼	7623	87¼
7	4489	31423	20948	144½	17956	134	15711	125½	13965	118¼	12569	112	11426	107	10474	102	9668	98¼	8978	94¾	8379	91½	7855	88½
8	4624	32368	21578	146¾	18496	136	16184	127¼	14385	120	12947	113¾	11770	108½	10789	103¾	9959	99¾	9247	96¼	8631	93	8092	90
9	4761	33327	22218	149	19044	138	16663	129	14812	121¾	13330	115¼	12119	110	11109	105½	10254	101¼	9522	97½	8887	94¼	8331	91¼
0	4900	34300	22866	151	19600	140	17150	131	15244	123½	13720	117	12472	111½	11433	107	10554	102¾	9800	99	9146	95½	8575	92½

TABLE IV. of the Powers of Steam Engines working at the Rate of 8lbs. Avoirdupoiſe, upon every Circular Inch, or 10.18 lbs. upon every Square Inch of the Steam Piſton, applicable to Blowing Machinery; and the Areas and Diameters of Blowing Cylinders requiſite to raiſe Air of various Denſities from 1½ lb. to 4 lbs. upon each Circular Inch, or from 1.90 lb. to 5,092 lbs. Avoirdupoiſe upon each Square Inch of the Air Receiver.

Diameter of Steam Cylind.	Area of Ditto.	Power of the Engine in Pounds.	Blaſt 1½ lb. per Circular Inch, or 1.90 lb. per Square Inch		Blaſt 1¾ lb. per Circular Inch, or 2.22 lb. per Square Inch.		Blaſt 2 lb. per Circular Inch, or 2.54 lb. per Square Inch.		Blaſt 2¼ lb per Circular Inch, or 2.86 lb. per Square Inch.		Blaſt 2½ lb. per Circular Inch, or 3.18 lb. per Square Inch.		Blaſt 2¾ lb. per Circular Inch, or 3.41 lb. per Square Inch.		Blaſt 3 lb. per Circular Inch, or 3.51 lb. per Square Inch.		Blaſt 3¼ lb. per Circular Inch, or 4.13 lb. per Square Inch.		Blaſt 3½ lb. per Circular Inch, or 4.77 lb. per Square Inch.		Blaſt 3¾ lb. per Circular Inch, or 4.77 lb. per Square Inch.		Blaſt 4 lb. per Circular Inch, or 5.09 lb. per Square Inch.	
			Area of blowing Cylinder.	Diameter of Ditto.	Area of blowing Cylinder	Diameter of Ditto	Area of blowing Cylinders	Diameter of Ditto	Area of blowing Cylinder.	Diameter of Ditto.	Area of blowing Cylinder.	Diameter of Ditto.	Area of blowing Cylinder.	Diameter of Ditto.	Area of blowing Cylinder.	Diameter of Ditto.	Area of blowing Cylinder	Diameter of Ditto.	Area of blowing Cylinder.	Diameter of Ditto.	Area of blowing Cylinder	Diameter of Ditto.	Area of blowing Cylind.	Diam. of Ditto.
20	400	3200	2133	46¼	1828	42¾	1600	40	1422	37¼	1280	36	1163	34	1066	32¼	984	31¼	914	30	853	29	800	28¼
21	441	3528	2352	48½	2016	45	1764	42	1568	39½	1412	37¼	1282	35¾	1176	34	1085	33	1008	31½	940	30½	882	29½
22	484	3872	2581	50¾	2212	47	1936	44	1720	41½	1548	39½	1408	37½	1290	35¾	1191	34½	1106	33	1032	32	968	31
23	529	4232	2821	53	2418	49	2116	46	1880	43¼	1692	41	1538	39	1410	37½	1302	36	1209	34¾	1128	33½	1058	32¼
24	576	4608	3072	55½	2633	51¼	2304	48	2048	45¼	1845	43	1675	41	1536	39	1417	37½	1316	36¼	1228	35	1152	33½
25	625	5000	3333	57¾	2857	53¼	2500	50	2222	47	2000	44¼	1818	42¾	1666	40½	1538	39	1428	37¾	1333	36½	1250	35
26	676	5408	3605	60	3090	55¼	2704	52	2403	48¾	2163	46½	1966	44½	1802	42¼	1664	40¾	1545	39¼	1442	38	1352	36¼
27	729	5832	3886	62¼	3332	57½	2916	54	2592	50½	2332	48¼	2120	46	1944	44	1794	42¼	1666	40¾	1555	39½	1458	37½
28	784	6272	4181	64½	3584	59½	3136	56	2787	52½	2508	50	2280	47¾	2090	45¾	1929	44	1792	42¼	1672	41	1568	39¼
29	841	6728	4485	67	3844	61¾	3364	58	2990	54½	2691	51¾	2446	49¼	2242	47½	2069	45½	1922	43¾	1794	42½	1682	41
30	900	7200	4800	69¼	4114	64	3600	60	3200	56½	2880	53¾	2618	51	2400	49	2215	47	2057	45¼	1920	44	1800	42½
31	961	7688	5125	71½	4393	66	3844	62	3417	58½	3075	55½	2795	52¾	2562	50½	2365	48½	2196	46¾	2050	45¼	1922	43¾
32	1024	8192	5461	74	4681	68¼	4096	64	3640	60½	3276	57¼	2989	54½	2730	52¼	2520	50	2340	48¼	2184	46½	2048	45¼
33	1089	8712	5808	76¼	4978	70¼	4356	66	3872	62½	3484	59	3168	56¼	2904	54	2680	51½	2489	50	2323	48	2178	46½
34	1156	9248	6165	78½	5284	72½	4624	68	4110	64¼	3699	60¾	3362	58	3082	55½	2845	53	2642	51½	2466	49½	2312	48
35	1225	9800	6533	81	5600	74¾	4900	70	4355	66	3920	62½	3563	59¾	3266	57	3015	54½	2800	53	2613	51	2450	49½
36	1296	10368	6912	83½	5924	77	5184	72	4608	68	4147	64¼	3770	61½	3456	58¾	3190	56¼	2962	54½	2764	52½	2592	51
37	1369	10952	7301	85¾	6258	79¼	5476	74	4867	69¾	4380	66¼	3982	63	3650	60¼	3308	58	3129	56	2920	53½	2738	52¼
38	1444	11559	7713	87¾	6601	80¾	5776	76	5134	71½	4620	68	4200	64¾	3850	62	3554	59½	3300	57½	3080	55¼	2888	53½
39	1521	12168	8112	90	6953	83	6084	78	5408	73¼	4867	69¾	4424	66½	4056	63½	3744	61	3476	59	3244	57	3042	54¾
40	1600	12800	8533	92¼	7314	85¼	6400	80	5688	75¼	5120	71½	4654	68¼	4266	65¼	3938	62½	3657	60½	3413	58½	3200	56¼
41	1681	13448	8965	94½	7684	87½	6724	82	5976	77¼	5379	73¼	4890	70	4462	66¾	4137	64	3842	62	3586	59¾	3362	58
42	1764	14112	9408	97	8064	89¾	7056	84	6272	79¼	5644	75	5131	71¾	4704	68½	4342	65½	4032	63½	3763	61¼	3528	59¼
43	1849	14792	9861	99¼	8453	92	7396	86	6574	81	5916	76¾	5378	73¼	4930	70¼	4520	67¼	4226	65	3944	62¾	3698	60¾
44	1936	15488	10325	101½	8450	94	7744	88	6883	83	6195	78½	5632	75	5162	71¾	4765	69	4425	66½	4130	64	3872	62¼
45	2025	16200	10800	104	9257	96¼	8100	90	7200	85	6480	80½	5890	76½	5400	73½	4984	70½	4628	68	4320	65¼	4050	63½
46	2116	16928	11285	106¼	9673	98½	8464	92	7523	86¾	6771	82¼	6155	78¼	5642	75	5208	72¼	4836	69½	4514	67	4232	65
47	2209	17672	11781	108½	10098	100¼	8836	94	7854	88¼	7068	84	6426	80	5890	76½	5437	73¾	5049	71	4712	68½	4418	66½
48	2304	18432	12288	110¾	10532	102¼	9216	96	8192	90¼	7372	85¾	6702	81¾	6144	78	5671	75½	5266	72½	4915	70	4608	68
49	2401	19208	12805	113¼	10976	104½	9604	98	8536	92	7683	87¼	6984	83½	6402	80	5910	77	5488	74	5122	71½	4802	69½
50	2500	20000	13333	115½	11428	106¼	10000	100	8888	94	8000	89½	7272	85¼	6666	81¾	6153	78½	5714	75½	5333	73	5000	71
51	2601	20808	13872	117¾	11888	109	10404	102	9248	96¼	8323	91¼	7566	87	6936	83¼	6403	80	5945	77	5548	74½	5202	72¼
52	2704	21632	14421	120	12361	111	10816	104	9614	98	8652	93	7866	88¾	7210	85	6656	81½	6180	78½	5768	76	5408	73½
53	2809	22472	14981	122¼	12841	113¼	11236	106	9987	100	8988	94¼	8135	90¼	7490	86½	6914	83	6420	80	5992	77½	561[illegible]	75
54	2916	23328	15552	124½	13330	115½	11664	108	10368	101¾	9331	96¼	8482	92	7776	88¼	7116	84½	6665	81½	6220	79	5[illegible]32	76½
55	3025	24200	16133	127	13828	117½	12100	110	10755	103½	9680	98	8800	93¾	8066	89¾	7446	86¼	6914	83	6453	80½	6050	78
56	3136	25088	16725	129¼	14336	119½	12544	112	11150	105¼	10035	100	9122	95½	8362	91½	7719	87¾	7168	84½	6690	82	6272	79¼
57	3249	25992	17328	131½	14852	121¼	12996	114	11552	107½	10396	101¾	9451	97¼	8664	93	7997	89¼	7426	86	6931	83¼	6408	80½
58	3364	26912	17940	134	15378	124	13456	116	11960	109½	10764	103½	9786	98¾	8970	94½	8280	91	7689	87½	7176	84½	6728	82
59	3481	27848	18565	136¼	15908	126	13924	118	12376	111¼	11139	105½	10126	100½	9282	96¼	8568	92½	7956	89	7426	86	6962	83½
60	3600	28800	19200	138½	16457	128¼	14400	120	12800	113	11520	107¼	10472	102¼	9600	98	8861	94¼	8228	90½	7680	87½	7200	85
61	3721	29768	19845	140¾	17010	130½	14884	122	13230	114¾	11907	109	10824	104	9922	99¾	9159	95¾	8505	92	7938	89	7442	86¼
62	3844	30752	20381	142¾	17572	132¼	15376	124	13676	117	12308	111	11182	105½	10250	101¼	9462	97¼	8786	93½	82[illegible]0	90½	7688	87½
63	3969	31752	21168	145	18144	134½	15876	126	14112	119	12700	112¾	11454	107¼	10584	102¾	9769	98¾	9072	95¼	8467	92	7938	89
64	4096	32768	21845	147¾	18724	136¼	16384	128	14563	120¾	13107	114½	11912	109	10922	104½	10082	100¼	9362	96¾	8738	94½	8192	90½
65	4225	33800	22533	149½	19314	139	16900	130	15022	122½	13520	116¼	12290	110¼	11266	106¼	10400	102	9657	98¼	9014	95	8450	92
66	4356	34848	23232	152	19913	141¼	17424	132	15488	124½	13939	118	12672	112¼	11614	107¾	10722	103½	9956	99½	9292	96½	87[illegible]2	93½
67	4489	35912	23941	154½	20521	143¼	17956	134	15960	126¼	14364	119¾	13058	114	11970	109½	11049	105	10260	101¼	9576	98	8978	95
68	4624	36992	24661	157	21138	145½	18496	136	16440	128	14796	121½	13451	116	12330	111	11382	106½	10569	103	9864	99¼	924[illegible]	96¼
69	4761	38088	25392	159½	21764	147½	19044	138	16924	130	15235	123¼	13847	117¾	12696	112¾	11719	108¼	10882	104½	10156	100½	9522	97½
70	4900	39200	26133	162	22400	149½	19600	140	17422	132	15680	125¼	14254	118½	13066	114½	12061	110	11200	106	10453	102¼	9800	99

TABLE V. of Blowing Cylinders, their Area, Capacity, and Quantity of Air, discharged by an Eight-Feet Stroke.

Diameter of Cylinders	Area in Circular Inches.	Area in Square Inches.	Capacity of the Stroke in Cubical Feet.	Air discharged at the Rate of 50 Cylinders per Minute in Cubical Feet.	Air discharged at the Rate of 40 Cylinders per Minute in Cubical Feet.	Air discharged at the Rate of 30 Cylinders per Minute in Cubical Feet.	Air discharged at the Rate of 25 Cylinders per Minute in Cubical Feet.	Air discharged at the Rate of 20 Cylinders per Minute in Cubical Feet.	Air discharged at the Rate of 15 Cylinders per Minute in Cubical Feet.	Air discharged at the Rate of 12 Cylinders per Minute in Cubical Feet.	Air discharged at the Rate of 10 Cylinders per Minute in Cubical Feet.
36	1296	1017.8784	56.5488	2827.4400	2261.9520	1696.4640	1413.7200	1130.9760	848.2320	678.5856	565.4880
37	1369	1075.8670	59.7340	2986.7000	2389.3600	1792.0200	1493.3500	1194.6800	896.0100	680.8080	597.3400
38	1444	1134.1176	63.0064	3150.3200	2520.2560	1890.1920	1575.1600	1260.1280	945.0960	756.0768	630.0640
39	1521	1194.5934	66.3662	3318.3100	2654.6480	1990.9860	1659.1550	1327.3240	995.4930	796.3944	663.6620
40	1600	1256.6400	69.8110	3490.5500	2792.4400	2094.3300	1745.2750	1396.2200	1047.1650	837.7320	698.1100
41	1681	1320.2574	73.3476	3667.3800	2933.9040	2200.4280	1833.6900	1466.9520	1100.2140	880.1712	733.4760
42	1764	1385.4456	76.9668	3848.3400	3078.6720	2309.0040	1924.1700	1539.3360	1154.5020	923.6016	769.6680
43	1849	1452.2046	80.6780	4033.9000	3227.1200	2420.3400	2016.9500	1613.5600	1210.1700	968.1360	806.7800
44	1936	1520.5344	84.4740	4233.7000	3378.9600	2534.2200	2116.8500	1689.4800	1267.1100	1013.6880	844.7400
45	2025	1590.4350	88.3574	4417.8700	3534.2960	2650.7220	2208.9350	1767.1480	1325.3610	1062.4488	883.5740
46	2116	1661.9064	92.3280	4616.4000	3693.1200	2769.8400	2308.2000	1846.5600	1384.9200	1107.9360	923.2800
47	2209	1734.9486	96.3860	4819.3000	3855.4400	2891.5800	2409.6500	1927.7200	1445.7900	1156.6320	963.8600
48	2304	1809.5616	100.5312	5026.5600	4021.2480	3015.9360	2513.2800	2010.6240	1507.9680	1206.3744	1005.3120
49	2401	1885.7545	104.7636	5238.1800	4190.5440	3142.9080	2619.0900	2095.2720	1571.4540	1255.1632	1047.6360
50	2500	1963.5000	109.0832	5454.1600	4363.3880	3272.4960	2727.0800	2181.6940	1636.2480	1308.9984	1090.8470
51	2601	2042.8254	113.4902	5674.5100	4539.6080	3404.7060	2837.2550	2269.8040	1702.3530	1361.8824	1134.9020
52	2704	2123.7216	117.9288	5896.4400	4717.1520	3537.8640	2948.2200	2358.5760	1768.9320	1415.1456	1179.2880
53	2809	2206.1886	122.5660	6128.3000	4902.6400	3676.9800	3064.1500	2451.3200	1838.4900	1470.7920	1225.6600
54	2916	2290.2264	127.2346	6361.7300	5089.3840	3817.0380	3180.8650	2544.6920	1908.5190	1526.8152	1272.3460
55	3025	2375.8350	131.9908	6599.5400	5279.6320	3959.7240	3299.7700	2639.8160	1979.8620	1583.8896	1319.9080
56	3136	2463.0144	136.8034	6840.1700	5472.1360	4104.1020	3420.0850	2736.0680	2052.0510	1641.6438	1368.0340
57	3249	2551.7646	141.7646	7088.2300	5670.5840	4252.9380	3544.1150	2835.2920	2126.9690	1701.1752	1417.6460
58	3364	2642.0856	146.7826	7339.1300	5871.3040	4403.4780	3669.5650	2935.6520	2201.7390	1751.3912	1467.8260
59	3481	2733.9774	151.8876	7594.3800	6075.5040	4556.6280	3797.1900	3037.7520	2278.3140	1812.6312	1518.8760
60	3600	2827.4400	157.0800	7854.0000	6283.2000	4712.4000	3927.0000	3141.6000	2356.2000	1884.9600	1570.8000
61	3721	2922.4734	162.3596	8117.9800	6494.3840	4870.7880	4058.9900	3247.1920	2435.3940	1948.3152	1623.5960
62	3844	3019.0776	167.7264	8386.3200	6709.0560	5031.7920	4193.1600	3354.5280	2515.8960	2012.7168	1677.2640
63	3969	3117.2526	173.1406	8657.0300	6925.6240	5194.2180	4328.5150	3462.8120	2597.1040	2077.6872	1731.4010
64	4096	3216.9984	178.6664	8933.3200	7146.6560	5359.9920	4466.6600	3573.3280	2679.9960	2144.1968	1786.6640
65	4225	3318.3150	184.3508	9217.5400	7374.0320	5530.5240	4608.7700	3687.0160	2765.2620	2212.2096	1843.5080
66	4356	3421.2024	190.0668	9503.3400	7602.6720	5702.0040	4751.6700	3801.3360	2851.0020	2280.8016	1900.1680
67	4489	3525.6606	195.8700	9793.5000	7834.8000	5876.1000	4896.7500	3917.4000	2938.0500	2350.4400	1958.7000
68	4624	3631.6896	201.7604	10088.0200	8070.4160	6052.8120	5044.0100	4035.2080	3026.4060	2421.1248	2017.6040
69	4761	3739.2894	207.7382	10386.9100	8309.5280	6232.1460	5193.4550	4154.7640	3116.0730	2492.8584	2077.3820
70	4900	3848.4600	213.8034	10690.1700	8552.1360	6414.1020	5345.0850	4276.0680	3207.0510	2565.6408	2138.0340
71	5041	3959.2014	219.9556	10997.7800	8798.2240	6598.6680	5498.8900	4399.1120	3299.3340	2639.4672	2199.5560
72	5184	4071.5136	226.1952	11309.7600	9047.8080	6785.8560	5654.8800	4523.9040	3392.9280	2714.3424	2261.9520
73	5329	4185.3966	232.5220	11626.1000	9300.8800	6975.6600	5813.0500	4650.4400	3487.8300	2790.2640	2325.2200
74	5476	4300.8504	238.9360	11946.8000	9557.4400	7168.0800	5973.4000	4778.7200	3584.0400	2867.2320	2389.3600
75	5625	4417.8750	245.4374	12271.8700	9817.4960	7363.1220	6135.9350	4908.7480	3681.0610	2945.2488	2454.3740
76	5776	4536.4704	252.0260	12601.3000	10081.0400	7560 7800	6300.6500	5040.5200	3780.3900	3024.3126	2520.2600
77	5929	4656.6366	258.6464	12932.3200	10345.8560	7759.3920	6466.1600	5172.9280	3879.6960	3103.7568	2586.4640
78	6084	4778.3736	265.4652	13273.2600	10618.6080	7963.9560	6636.6300	5309.3040	3981.9780	3185.5824	2654.6520
79	6241	4901.6814	272.3156	13615.7800	10892.6240	8169.4680	6807.8900	5446.3120	4084.7340	3267.7872	2723.1560
80	6400	5026.5600	279.2530	13962.6500	11170.1200	8377.5900	6981.3250	5585.0600	4188.7950	3351.0360	2792.5300
81	6561	5153.0094	286.2782	14313.9100	11451.1280	8588.3460	7156.9550	5725.5640	4294.1730	3435.3834	2862.7820
82	6724	5281.0296	293.3904	14669.5200	11735.6160	8801.7120	7334.7600	5867.8080	4400.8560	3520.6848	2933.9040
83	6889	5410.6206	300.5900	15029.5000	12023.6000	9017.7000	7514.7500	6011.8000	4508.8500	3607.0800	3005.9000
84	7056	5541.7824	307.8772	15393.8600	12315.0880	9236.3160	7696.9300	6157.5440	4618.1580	3694.5264	3078.2720
85	7225	5674.5150	315.2508	15762.5400	12610.0320	9457.5240	7881.2700	6305.0160	4728.2620	3783.0096	3152.5080
86	7396	5808.8184	322.7120	16135.6000	12908.4800	9681.3600	8067.8000	6454.2400	4840.6800	3872.5440	3227.1200
87	7569	5944.6926	330.2606	16513.0300	13210.4240	9907,8180	8256.0150	6655.2120	4953.9090	3963.1272	3327.6060
88	7744	6082.1376	337.8964	16894.8200	13515.8560	10136.8920	8447.4120	6757.4280	5068.4460	3054.7568	3378.7140
89	7921	6221.1534	345.6196	17280.9800	13824.7840	10368.5880	8640.4900	6912.3920	5184.2940	4147.4352	3456.1960
90	8100	6361.7400	353.4300	17671.5000	14137.2000	10602.9000	8835.7500	7068.6000	5301.4500	4241.1600	3534.3000
91	8281	6503.8974	361.3276	18066.3800	14453.1040	10839.8280	9033.1900	7226.5520	5419.9140	4335.9312	3613.2760
92	8464	6647.6256	369.3124	18465.6200	14772.4960	11079.3720	9232.8100	7386.2480	5539.6860	4431.7488	3693.1240
93	8649	6792.9246	377.3846	18869.2300	15095.3840	11321.5380	9434.6150	7547.6920	5660.7690	4528.6152	3773.8460
94	8836	6939.7944	385.5440	19277.2000	15421.7600	11566.3200	9638.2000	7710.8800	5783.1600	4626.5280	3855.4400
95	9025	7088.2250	393.7908	19689 5400	15751.6320	11813.7240	9844.7700	7875.8160	5906.8620	4725.4896	3937.9080
96	9216	7238.2464	402.1252	20106.2600	16085.0080	12063.7560	10053.1300	8042.5040	6031.8780	4825.5024	4021.2520
97	9409	7389.8286	410.5460	20527.3000	16421.8400	12316.3800	10263.1500	8210.9200	6158.1900	4926.5520	4105.4600
98	9604	7542.9816	419.0544	20952.7200	16762.1760	12571.6320	10476.3600	8381.0880	6285.8160	5028.6528	4190.5440
99	9801	7697.7054	427.6502	21382.5100	17106.0080	12829.5060	10691.2550	8553.0040	6414.7530	5131.8024	4276.5020
100	10000	7854.0000	436.3332	21816.6600	17453.3280	13089.9960	10908.3300	8726.6640	6544.9980	5235.9984	4363.3320

TABLE VI. of the Powers of Steam Engines working at the Rate of 10lbs. Avoirdupoise upon every Circular Inch, or 12.73 lbs. upon every Square Inch of the Steam Piston applicable to Blowing Machinery; and the Areas and Diameters of Blowing Cylinders requisite to raise Air of various Densities from 1½lb. to 4lbs. Avoirdupoise upon each Circular Inch, or from 1.90lb. to 5.092lbs. upon each Square Inch of the Air Receiver.

Diameters of Steam Cyl.	Areas of Ditto.	Power of the Engine in Pounds.	Blast 1½ lb. per Circular Inch, or 1.90 lb. per Square Inch.		Blast 1¾ lb. per Circular Inch, or 2.22 lb. per Square Inch.		Blast 2 lb. per Circular Inch, or 2.54 lb. per Square Inch.		Blast 2¼ lb. per Circular Inch, or 2.86 lb. per Square Inch.		Blast 2½ lb. per Circular Inch, or 3.18 lb. per Square Inch.		Blast 2¾ lb. per Circular Inch, or 3.41 lb. per Square Inch.		Blast 3 lb. per Circular Inch, or 3.81 lb. per Square Inch.		Blast 3¼ lb. per Circular Inch, or 3,81 lb. per Square Inch.		Blast 3½ lb. per Circular Inch, or 4.45 lb. per Square Inch.		Blast 3¾ lb. per Circular Inch, or 4.77 lb. per Square Inch.		Blast 4 lb. per Circular Inch, or 5.09lb. per Square Inch.	
			Area of blowing Cylinder.	Diameter of Ditto.	Area of blowing Cylinder.	Diameter of Ditto.	Area of blowing Cylinder.	Diameter of Ditto.	Area of blowing Cylinder.	Diameter of Ditto.	Area of blowing Cylinder.	Diameter of Ditto.	Area of blowing Cylinder.	Diameter of Ditto.	Area of blowing Cylinder.	Diameter of Ditto.	Area of blowing Cylinder.	Diameter of Ditto.	Area of blowing Cylinder.	Diameter of Ditto.	Area of blowing Cylinder.	Diameter of Ditto.	Area of blowing Cylinder.	Diameter of Ditto.
20	400	4000	2666	51½	2285	47¾	2000	44¾	1777	42	1600	40	1454	38	1333	36½	1230	35	1142	34	1066	32½	1000	31½
21	441	4410	2940	54¼	2520	50¼	2205	47	1960	44¼	1764	42	1603	40	1470	38¼	1356	36½	1260	35½	1176	34¼	1102	33½
22	484	4840	3226	57	2765	52½	2420	49¼	2151	46½	1936	44	1760	42	1613	40	1489	38¼	1382	37	1290	36	1210	35
23	529	5290	3526	59½	3022	55	2645	51¼	2351	48¼	2116	46	1923	44	1763	42	1627	40¼	1511	38¾	1410	37¼	1322	36½
24	576	5760	3840	62	3291	57¼	2880	53½	2560	50½	2304	48	2094	43¾	1920	44	1772	42	1645	40½	1536	39¼	1440	38
25	625	6250	4160	64½	3571	59¾	3125	56	2777	52½	2500	50	2272	47	2083	45½	1923	44	1785	42	1666	40¼	1562	39½
26	676	6760	4506	67	3862	62	3380	58¼	3004	53¾	2704	52	2458	49	2253	47½	2080	45½	1931	44	1802	42¼	1690	41
27	729	7290	4860	69½	4165	64¼	3645	60¼	3240	57	2916	54	2650	51¼	2430	49¼	2243	47½	2082	45½	1944	44	1822	42½
28	784	7840	5226	72	4480	67	3920	62¼	3484	59	3136	56	2850	53¼	2613	51	2414	49	2240	47¼	2090	45¼	1960	44
29	841	8410	5606	74½	4805	69¼	4205	64¾	3737	61	3364	58	3058	55¼	2803	53	2587	50½	2402	49	2242	47¼	2102	45¾
30	900	9000	6000	77½	5142	71¾	4500	67	4000	63	3600	60	3272	57¼	3000	54¾	2769	52½	2571	50¾	2400	49	2250	47
31	961	9610	6406	80	5491	74	4805	69¼	4271	65¼	3844	62	3494	59	3203	56½	2958	54¼	2745	52¼	2562	50½	2402	49
32	1024	10240	6826	82½	5851	76½	5120	71½	4560	67¼	4096	64	3723	61	3413	58½	3150	56	2925	54	2730	52¼	2560	50½
33	1089	10890	7260	85¼	6222	79	5495	74	4842	69½	4356	66	3960	63	3630	60¼	3350	58	3111	55¾	2904	54	2722	52¼
34	1156	11560	7706	87¾	6605	81¼	5780	76	5137	71½	4624	68	4203	65	3853	62	3556	59½	3302	57½	3082	55½	2890	54
35	1225	12250	8166	90½	6999	83¾	6125	78¼	5444	73¾	4900	70	4454	67	4083	64	3781	61½	3500	59½	3266	57	3062	55¾
36	1296	12960	8640	93	7405	86	6480	80½	5760	76	5184	72	4712	68¾	4320	65¾	3987	63	3702	61	3456	58¾	3240	57
37	1369	13690	9126	95½	7822	88½	6845	83	6084	78	5476	74	4978	70½	4653	67¼	4212	65	3911	62¾	3650	60½	3422	58½
38	1444	14440	9626	98	8251	90¼	7220	85	6417	80	5776	76	5250	72¼	4813	69½	4443	66½	4125	64	3850	62	3610	60
39	1521	15210	10140	100½	8691	93¼	7605	87½	6760	82¼	6084	78	5530	74¼	5070	71¼	4680	68¼	4345	66	4056	63¾	3802	61½
40	1600	16000	10666	103	9142	95½	8000	89½	7111	84½	6400	80	5818	76½	5333	73	4920	70	4571	67½	4266	65¼	4000	63
41	1681	16810	11026	105¾	9605	98	8405	91½	7471	86½	6724	82	6112	78¼	5603	75	5172	72	4802	69½	4482	67	4202	64¾
42	1764	17640	11760	108½	10080	100¼	8820	94	7840	88½	7056	84	6414	80	5880	76¾	5427	73¼	5040	71	4704	68¾	4410	66½
43	1849	18490	12326	111	10565	102½	9245	96	8217	90½	7396	86	6723	82	6163	78½	5689	75½	5282	72½	4930	70¼	4622	68
44	1936	19360	12906	113½	11062	105	9680	98¼	8604	92¾	7744	88	7040	84	6453	80¼	5956	77¼	5531	74¼	5162	72	4840	69½
45	2025	20250	13500	116¼	11571	107½	10125	100½	9000	95	8100	90	7363	85¾	6750	82	6220	79	5785	76	5400	73½	5062	71
46	2116	21160	14106	118¾	12091	110	10580	102½	9404	97	8464	92	7694	87½	7053	84	6510	80½	6045	77½	5642	75¼	5290	72½
47	2209	22090	14726	121½	12622	112¾	11045	105	9817	99	8836	94	8032	89½	7363	86	6798	82½	6311	79½	5890	76¾	5522	74¼
48	2304	23040	15360	124	13166	114¾	11520	107	10244	101¼	9216	96	8378	91½	7680	87¾	7089	84¼	6582	81	6144	78½	5760	76½
49	2401	24010	16006	126½	13720	117	12005	109½	10671	103[illegible]	9605	98	8730	93½	8003	89½	7387	86	6860	82¾	6402	80	6002	77¾
50	2500	25000	16666	129	14285	119½	12500	111¾	11111	105[illegible]	10000	100	9090	95¼	8333	91¼	7692	87¾	7142	84¼	6666	81½	6250	79
51	2601	26010	17340	131½	14862	122	13005	114	11560	107[illegible]	10404	102	9458	97¼	8670	93	8003	89½	7431	86	6936	83¼	6502	80½
52	2704	27040	18026	134	15451	124½	13520	116¼	12017	109[illegible]	10816	104	9832	99	9013	95	8320	91¼	7725	87¾	7210	85	6760	82½
53	2809	28090	18726	136¾	16051	126¾	14045	118½	12484	111[illegible]	11236	106	10214	101	9363	96¾	8643	93	8025	89½	7490	86½	7022	84
54	2916	29160	19440	139¼	16662	129	14580	120¾	12960	113¾	11664	108	10603	103	9720	98½	8972	94¾	8331	91¼	7776	88¼	7290	85½
55	3025	30250	20166	142	17285	131½	15125	123	13444	116	12100	110	11000	105	10832	100¼	9307	96	8642	93	8066	89¾	7562	87
56	3136	31360	20906	144½	17920	133¾	15680	25¼	13937	118	12544	1.2	11403	106¾	10453	102	9649	98¼	8960	94½	8362	91½	7840	88½
57	3249	32490	21660	147¼	18565	136¼	16245	127½	14440	120	12996	114	11814	108¾	10830	104	9997	100	9282	96½	8664	93	8122	90
58	3364	33640	22426	149¾	19222	138½	16820	129¾	14951	122	13456	116	12232	110½	11214	106	10350	101¾	9611	98	8970	94½	8410	91½
59	3481	34810	23206	152½	19891	141	17405	132	1542	124	13924	118	12658	112½	11603	107½	10710	103½	9943	99¾	9282	96¼	8702	93
60	3600	36000	24000	155	20571	143¼	18000	134¼	16000	126¼	14400	120	13090	114½	12000	109½	11077	105½	10285	101¼	9600	98	9000	94¾
61	3721	37210	24806	157½	21252	145¾	18605	136¼	16537	128½	14884	122	13530	1 6¼	12403	111¼	11449	107	10631	102¾	9922	99¼	9302	96½
62	3844	38440	25626	160	21965	148¼	19220	138½	17084	130½	15376	124	13978	118¼	12813	113¼	11827	108¾	10982	104¾	10250	100½	9610	98
63	3969	39690	26460	162½	22622	150½	19845	140¾	17640	132¾	15876	126	14436	120	13230	115	12212	110½	11340	106¼	10584	103	9922	99½
64	4096	40960	27306	165¼	23405	153	20480	143	18204	135	16384	128	14894	122	13653	117	12603	112½	11702	108	10922	104½	10240	101½
65	4225	42250	28166	167¾	24142	155¼	2,125	145¼	18777	137	16900	130	15363	124	14083	118¾	13000	114	12071	109¾	11266	106	10562	102½
66	4356	43560	29040	170½	24891	157¾	21780	147¼	19360	139¼	17424	132	15840	126	14520	120½	13403	115¼	12445	111½	11616	107½	10890	104½
67	4489	44890	29926	173	25651	160¼	22445	149½	1995	141½	17956	134	16324	127¾	14963	122¼	13812	117½	12825	113¼	11970	109¼	11222	106
68	4624	46240	30826	175½	26422	162¾	23120	152	20551	143½	18496	136	16814	129½	15413	124¼	14227	119½	13211	115	12330	111	11560	107½
69	4761	47610	31740	178¼	27205	165	23805	154¼	21160	145½	19044	138	17309	131½	15870	126	14646	121	13602	116¾	12696	112¾	11902	109
70	4900	49000	32666	180½	28000	167½	24500	156½	21777	147½	19600	140	17818	133½	16333	128	15076	123	14000	118½	13066	114¼	12250	110½

Boiler

BOILER, or BOYLER, a large copper veſſel, wherein things are expoſed over the fire to be boiled.

The boiler, in the alum-works, is a veſſel, in which the liquor is evaporated to a conſiſtence, and is made of lead. The general ſize is about eight feet ſquare, and they contain about twelve tons each.

They make them in this manner: firſt, they lay long pieces of caſt-iron, twelve inches ſquare, as long as the

breadth of the boiler, and at about twelve inches diſtance from one another. Theſe are placed twenty-four inches above the ſurface of the fire. On theſe maſſy bars of iron they lay, croſs-wiſe, the common flat bars of iron, as cloſe as they can lie together, and then make up the ſides with brick-work. In the middle of the bottom of this boiler is laid a trough of lead, wherein they put at firſt about a hundred pound weight of the rock. They uſe Newcaſtle coals in the boiling; and if they find the liquor not ſtrong enough, they add more of the rock at times, as it boils. Phil. Tranſ. N° 142.

The boiler for making colours, &c. muſt be made of pewter; becauſe iron and copper will be corroded by the ſaline ſubſtances uſed in the manufacture of them.

Count Rumford (See his Eſſays, vol. i. p. 220.) recommends double bottoms to boilers, and alſo to ſaucepans and kettles of all kinds, uſed for culinary purpoſes; which contrivance, he ſays, will, in all caſes, moſt effectually prevent what is called by the cooks, "burning-to." The heat is ſo much obſtructed in its paſſage through the thin ſheet of air which, notwithſtanding all the care that is taken to bring the two bottoms into actual contact, will ſtill remain between them, that the ſecond has time to give its heat as faſt as it receives it to the fluid in the boiler; and conſequently it never requires a degree of heat ſufficient for burning any thing that may be upon it. He ſuggeſts that it will probably be beſt to double copper ſaucepans and ſmall kettles throughout; and as this may and ought to be done with a very thin ſheet of metal, it would not coſt much, even if the lining were to be made of ſilver. When the two ſheets of metal that form the double bottoms of boilers are made to touch each other throughout, by hammering them together after the falſe bottom has been fixed in its place, they may be tacked together by a few ſmall rivets placed here and there, at conſiderable diſtances from each other; and when this is done, the boiler may be tinned. In this operation, if proper care be taken, the edge of the falſe bottom may be ſoldered by the tin to the ſides of the boiler, and thus the water or other liquids, put into the boiler, will be prevented from getting between the two bottoms. The Count adds, that this invention of double bottoms might be uſed with great ſucceſs by diſtillers, to prevent their liquor, when it is thick, from burning to the bottom of their ſtills. (See STILL.) Having found in the courſe of his experiments, (See Phil. Tranſ. 1792, Part I.) that confined air is the beſt barrier that can be oppoſed to heat for the purpoſe of confining it, he propoſed to confine the heat in the boilers of his conſtruction, and to prevent its eſcape into the atmoſphere, by means of double covers. Theſe covers were made of tin, or rather of thin iron-plates tinned, in the form of a hollow-cone; the height of the cone being equal to about one-third of its diameter; and thus the air which it contained was entirely ſhut up, the bottom of the cone being cloſed by a circular plate or thin ſheet of tinned iron. The bottom of the cone was accurately fitted to the top of the boiler, which it completely cloſed by means of a rim about two inches wide, which entered the boiler; which rim was ſoldered to the flat ſheet of tinned iron that formed the bottom of the cover. The ſteam, generated by the boiling liquid, was carried off by a tube about half an inch in diameter, which paſſed through the hollow conical cover, and which was attached to the cover, both above and below, with ſolder, in ſuch a manner that the air with which the hollow cone was filled remained completely confined, and cut off from all communication with the external air of the atmoſphere, as well as with the ſteam it generated in the boiler. For his various contrivances in the moſt advantageous conſtruction of boilers for the ſaving of fuel, and for producing the deſired effect, we refer to his Eſſays, vol. ii. p. 18, &c.

BOILERY, or BOILARY, in the *Salt Works*, denotes a ſalt-houſe, pit, or other place, where ſalt is made.

BOILING OF MEAT, in *Cookery*, is the expoſing of meat to the heat of boiling water, while it is immerſed in it for a certain time. By this joint application of heat and moiſture, the texture is rendered more tender and more ſoluble in the ſtomach; and it is only in this way, that the firmer parts, as the tendinous, ligamentous, and membranous parts can be duly ſoftened, and their gelatinous ſubſtance duly extracted. A moderate boiling renders the texture of animal fleſh more tender, without much diminution of its nutritious quality; but if the boiling is extended to extract every thing ſoluble, the ſubſtance remaining becomes leſs ſoluble in the ſtomach, and at the ſame time much leſs nutritious. But as boiling extracts in the firſt place the more ſoluble, and therefore the ſaline parts; ſo the remainder, after boiling, is in proportion to the continuance of the operation leſs alkaleſcent, and leſs heating to the ſyſtem.

Boiling is commonly practiſed in open veſſels, or in veſſels not cloſely covered; but it may be performed in digeſters, or veſſels accurately and tightly cloſed; and in ſuch veſſels the effects are very different from thoſe that take place in open veſſels. As we can hardly employ any other degree of heat than that of boiling water, the water in the digeſter is never made to boil, ſo there is no exhalation of volatile parts; and, although the ſolution is made with great ſucceſs, and may be to any degree required, yet if it be not carried very far, the meat may be rendered very tender, while it ſtill retains its moſt ſapid parts; and this kind of cookery will always give the moſt deſirable ſtate of boiled meat. Boiling, in the ordinary way, is different, according to the proportion of water that is applied. If a ſmall quantity be applied, and the heat in a moderate degree is continued for a long time, this is called "ſtewing," and has the effect of rendering the texture more tender, without extracting much of the ſoluble parts; and of courſe it leaves the meat more ſapid, and ſufficiently nouriſhing. Cullen's Mat. Med. vol. i. p. 400, &c.

BOILING, *ebullition*, in *Phyſics*, is the internal commotion excited in a maſs of water or other liquefied ſubſtance, by the ſucceſſive converſion of the lower portions of the fluid into vapour, and their violent effort under this expanſive and elaſtic form to make their eſcape. It is uſually, though not neceſſarily, produced by the application of heat. The circumſtances which precede or accompany the phenomenon of boiling, are beſt obſerved in a thin tranſparent flaſk nearly filled with water, and ſuſpended over a lamp or a charcoal fire. Numerous minute globules are ſeen collecting from all points towards the ſides and riſing in a ſtream to the ſurface; occaſioned evidently by the diſcharge of air, which is always in ſome proportion combined with water. As the heat increaſes, the liquid particles near the bottom of the flaſk ſuddenly burſt into ſteam, and ſhoot upwards; but in aſcending through the colder maſs, they again collapſe, ſtop their progreſs, and ſeem loſt. Such alternate expanſions and contractions, by throwing the fluid into a gentle tremor, frequently cauſes a peculiar ſort of ſinging noiſe, which is rightly ſuppoſed to betoken the approach of actual boiling. This ſinging is more likely to happen in the caſe where heat is applied partially; for inſtance, if a tea-kettle be placed at the ſide of the fire, ſince the heat is then more ſlowly and unequally diffuſed through the body of the water. But after the whole contents being fully penetrated, are warmed up to the requiſite degree of intenſity, the ſteam, as faſt as it is

formed, ascends continually and escapes unimpaired through the fluid, which it, therefore, heaves with violent agitation.

The same appearance almost is produced by removing or even diminishing the atmospheric pressure. Thus, if a tumbler holding warm water be introduced under the receiver of an air-pump, as the exhaustion proceeds, or the incumbent weight is gradually withdrawn, the latent portion of air is discharged in a rapid flow of expanded bubbles. But this process, at some certain point of rarefaction, is succeeded by the vehement commotion which constitutes boiling; and the water, assuming its invisible form, fills the imperfect void with vapour, which betrays its existence by condensing against the sides of the receiver in copious dew. Nor is heat positively necessary towards vaporization, for it only conspires in accomplishing that effect, and supplies the want or the imperfection of our means of producing exhaustion. By help of an air-pump of the best construction, the coldest water may be made to boil, nay, ice itself could be changed into invisible steam. Hence the utter impossibility of ever obtaining a perfect *vacuum*, because the restraining influence of pressure being entirely removed, the liquid matter unavoidably presented would always diffuse a thin vapour.

The opposite influence of heat and pressure on the constitution of fluids is well exhibited by a very simple yet striking experiment. Take a large thin phial, and having warmed it gradually to avoid the risk of cracking the glass, fill it completely with boiling water, cork it tight, and expose it to a current of cold air. As the water cools, it necessarily contracts its volume, and leaving an imperfect vacuity below the neck of the phial, it hence becomes to a considerable degree relieved from the load of atmospheric pressure. It therefore soon begins again to boil, nay, it will boil more briskly the faster it cools; and this singular appearance, so contrary to our usual notions, may continue perhaps for the space of half an hour, till the water has grown as cold almost as the temperature of the human body. On the same principle depends the construction of what is called the *pulse glass*: this consists of two balls connected by a pretty long tube; one of these balls is filled with coloured water or spirits of wine, which having been made to boil and expel the air by its vapour, at the same instant the point projecting from the other ball is hermetically sealed. As that vapour condenses with cold, it will leave the included liquid then in a sort of vacuum, and the heat of the hand is then sufficient to cause it to boil and to flow from one ball into the other.

If a vessel containing water be placed over a steady fire, the water will grow continually hotter till it reaches the limit of boiling, after which the regular accessions of heat are wholly spent in converting it into steam. The water therefore remains at the same pitch of temperature, however fiercely it boils. The only difference is that, with a strong fire, it sooner comes to boil, and more quickly boils away. Hence the reason why a vessel full of water, and plunged into the centre of a larger one, which is likewise filled with that fluid, barely acquires the boiling heat, but will never actually boil.

The formation of steam occasions a prodigious consumption of heat; for if the time be noted in which water, by the action of a strong fire, is raised from the limit of freezing to that of boiling, it will be found to require more than five times longer a space to boil entirely away. Thus, a portion of heat corresponding to above 900 degrees by Fahrenheit's scale, is always consumed in the act of boiling, or rather it is transferred and enters into the composition of steam, the gaseous product. This absorbed heat is as constantly evolved when steam condenses and returns to its liquid form. Hence in distillation a very large refrigeratory is required for condensing a comparatively small quantity of aqueous or spirituous vapour. Hence too the explication of the familiar remark that steam scalds more cruelly than boiling water.

The heat of boiling water, being subject to the influence of the atmospheric pressure, is thus not absolutely fixed. It varies with the variation of the barometer, and decreases as the mercury descends. The extent of this fluctuation may in our changeable climate amount to five degrees by Fahrenheit's scale, the successive difference of a degree corresponding nearly to each twentieth part of the remaining incumbent weight. On the tops of lofty mountains water will boil much sooner than in the plains below. This curious fact has been noticed by several travellers, and was particularly observed by Saussure on the summit of Mont Blanc. A still greater variation would be experienced on the peak of Chimboraco, the highest point of the Andes, where water would boil with a heat scarcely superior to that which is commonly assigned for the boiling of spirits of wine.

It is therefore evident that, under an augmented pressure, all liquids will more slowly reach the crisis of ebullition and will then have acquired a more intense heat. Thus water may be heated up many degrees above the mean point of boiling, if it be subjected to the action either of condensed air or of confined steam. Such is the principle of *Papin's Digester*; which, being nearly filled with water, is shut perfectly close, and set on a good fire. As the steam so formed is prevented from escaping, it necessarily concentrates, and exerting accumulated energy, it by its prodigious compression enables the water continually to receive additional heat. Nor would this progress at all stop, till the elasticity of the imprisoned vapour comes to surmount every obstacle, and bursts the vessel with terrible explosion. Accidents of that sort are extremely dangerous, and the experiment has consequently never been pushed to its utmost practicable limits. When the fracture takes place, not only the confined steam is liberated, but the pressure being now removed, the excess of heat instantaneously converts a part or the whole of the water likewise into steam, which augments the general effect. This we may perceive in the bursting of a glass cracker; for the little base is shivered into atoms, and the water which it contained is entirely dispersed, beating down flat the wick of the candle by the violence of the sudden expansive blast.

Hence the boiling heat of a deep cauldron is always rather greater than that of a shallow pan. This excess we might estimate at nearly one degree of Fahrenheit, for each foot of depth. The heat of ebullition must also rise somewhat higher, if the steam be not allowed to escape as fast as it is generated; for which reason there may be a slight difference of energy between rapid and slow boiling. Hence by the combined operation of both these causes, water deeply lodged in the bowels of the earth, or concealed under the dark bed of the ocean, is capable of acquiring the most intense heat from the action of subterranean fires; a principle of which Dr. Hutton has ingeniously availed himself in framing his Theory of the Earth.

But the position of the boiling point is likewise modified by the influence of chemical attraction. Thus sugar, common salt, and other saline substances, have all of them a tendency to fix water and retard the crisis of its conversion into elastic vapour. Strong brine will not boil until it is heated up several degrees above the ordinary limit. Hence a vessel containing fresh water, and immersed in another which is filled with brine, will gently boil, while the surrounding fluid only simmers. On the other hand, the addi-

tion of alcohol renders water more volatile. In the diſtillation of ſpirits, the fermented liquor in the copper boils always at a lower temperature, or at ſome intermediate point between the ebullition of water and that of alcohol. The ſpirituous fumes which riſe carry along with them a portion of evaporated water. Hence the neceſſity of rectification, or repeated diſtillations, to procure alcohol in its pureſt ſtate; for the boiling heat is lowered, and conſequently the proportion of aqueous admixture is diminiſhed, at each ſucceſſive proceſs. See DIGESTER, EBULLITION, FIRE, FLUID, HEAT, PRESSURE, STEAM, VAPOUR.

BOILING *of ſilk with ſoap*, is the firſt preparation in order to dyeing it. Thread is alſo *boiled* in a ſtrong *lixivium* of aſhes, to prepare it for dyeing.

Boiling is alſo a part of the proceſs for bleaching warp linen.

Boring

BORING, the act of perforating a ſolid body, or making a hole throughout its whole length or thickneſs.

Surgeons ſpeak of boring the bones of the ſcull, properly called trepanning.

Boring *birch*, and other trees, is practiſed in the ſpring for their juice, called alſo *tapping* and *bleeding*. Phil. Tranſ. N 44. p. 880. See Betula.

Boring, in *Farriery*, an operation formerly practiſed for the cure of horſes whoſe ſhoulders are wrenched. The method is thus: they cut a hole through the ſkin in the middle of the ſhoulder, and with the ſhank of a tobacco pipe, blow it as a butcher does a ſhoulder of veal; then they run a cold flat iron, like a horſeman's ſword-blade, eight or ten inches up, between the ſhoulder blade and the ribs, which they call boring; after that they burn him round his ſhoulder with a hot iron. This, ſays Bartlett, is an abſurd and uſeleſs, as well as a cruel practice.

Boring *of Cannon*, in *Foundery*. See Cannon.

Boring *of Maſts*, from top to bottom, is propoſed by Dr. Hook, as a means of ſtrengthening and preſerving them; as this would make them dry and harden the better, and prevent their cleaving and cracking. For want of this the outſide drying, when the inſide does not, the former ſhrinks faſter than the latter; the conſequence of which is prejudicial.

Boring, in *Mineralogy*, a method of piercing the earth by a ſet of ſcooping irons, made with joints ſo as to be lengthened at pleaſure. The ſkilful mineraliſt will be able to gueſs where a vein of ore may lie, though there are none of the common outward ſigns of it upon the ſurface of the earth; and in this caſe he has recourſe to boring; the ſcooping irons are drawn back at proper times, and the ſamples of earth and mineral matters they bring up, are examined; and hence it is known whether it will be worth while or not to open a mine in the place. See Coal.

Boring, in *Rural Economy*, a practice ſometimes employed in order to aſcertain the nature of the different ſtrata that lie beneath the ſurface ſoil; and alſo for the purpoſe of diſcovering ſprings, and tapping them, ſo as to draw off the water that injures the grounds below, or in the neighbourhood. When this laſt object is in view, boring is generally performed in the bottoms of ditches or drains, previouſly made in the land, to the depth of ſeveral feet. See Draining *of Land*.

Boring *Augre*, an implement employed for the purpoſe of boring the ſoil, and letting off water confined beneath it, &c. See Borer.

Boring *of Water-pipes*. The method of boring alder poles for water-pipes is thus: being furniſhed with poles of a fit ſize, horſes, or treſſels are procured of a due height both to lay the poles, and reſt the augre on in boring; they alſo ſet up a lath, whereby to turn the leſſer ends of the poles, and adapt them to the cavities of the greater ends of others, in order to make the joint ſhut each pair of poles together. The outer, or concave part, is called the female, and the other, or inner, the male part of the joint. In turning the male part, they make a channel, or ſmall groove in it, at a proper diſtance from the end; and in the female part, bore a ſmall hole to fit over this channel; they then bore through their poles, ſticking up great nails at each end to guide them right; but they commonly bore a pole at both ends; ſo that if it be crooked one way, they can nevertheleſs bore it through, and not ſpoil it. Neve Build. Dict. in voc. Alder.

This operation is now performed with a horſe-mill, as at Dorſet Stairs for the New River company.

Belidor, in his Hydraulics, has deſcribed a machine, in which a water-wheel is made uſe of both to turn the augre, and to bring forward the carriage on which the pipe to be bored reſts. This machine (ſee *Tab.* II. *Mechanics*, *fig.* 67.) is put into motion by the water-wheel A, in the axis of which there is a cog-wheel B, that turns the lanterns C and D; the trundles of D turn two ſmall wheels E and F; the firſt of which is vertical and turns the augre; the other is horizontal and moves the carriage by means of the two arms H and I. H draws the wheel G towards F; and I puſhes it in a contrary direction; and theſe combined actions cauſe the carriage to advance towards F, and the augre to bore the pipe. The augre being about twelve feet long and proportionally heavy, is ſupported by the pieces L L; and they are prepared ſo as to give no obſtruction, in the following manner: CC, (*fig.* 68.) are two planks of wood which are faſtened to the timber-work of the mill; theſe encompaſs another plank, hung by a cord, at the bottom of which are fixed the pieces *bb*, with joints at *e* and *e*, and, that they may not move out of the vertical plane, they are joined by tenons to the plank *a*, in which they may work freely: on the ſide of one of theſe pieces is fixed a ſpring, *g*, in order to hinder them from uniting, by forcing them into a mortiſe, in *d*; in this ſituation the two pieces are penetrated with a hole through which the augre is to paſs. The cord is faſtened to the plank *a*, as in *fig.* 69, and goes over the two pullies *bb*; at the other end of the cord there is hung a weight *e*, reſting on the piece N, which is ſupported at one end by the piece O, and fixed to the other by a joint to the lever K, which has its centre of motion in the piece of wood H; ſo that, leaning againſt the extremity M of the lever, N quits the ſupport O, the weight ſinks down, and draws up the piece *a*; then the ſides *bb*, *fig.* 68, quit the mortiſe *d*, and the ſpring *g* ſeparates them: and thus the ſupporter does not in the leaſt hinder the motion of the augre.

Boyle

Boyle, Robert, an eminent philosopher, illustrious by birth, learning, and virtue, was the 7th son of Richard, earl of Cork; and born at Lismore in the county of Cork, February 25th, 1726-7. In his infancy he was committed to the care of a country nurse, with instructions to bring him up hardily, as if he were her own son; and he thus acquired a strong and vigorous constitution, which was afterwards enfeebled by too tender treatment. About the age of 3 years, he lost his mother, whom he mentions with great respect; and whilst he was under the care of his nurse he acquired, by imitating some children of his own age, a habit of stuttering, which was never entirely cured. In his father's house he was taught to write a fair hand, and to speak both French and Latin; and at this early period he manifested a docility and an invariable regard to truth, which very much endeared him to his father, and formed distinguishing features of his character in the progress of his life. In 1635, when he was about eight years of age, he was sent to Eton college, of which sir Henry Wotton was then provost, and placed under the care of Mr. Harrison, to whose attention and judicious mode of instruction he acknowledged himself indebted for those habits of assiduous investigation in which he afterwards excelled. At Eton he was afflicted with an ague, which rendered it advisable to divert his attention from the course of study which he was pursuing, and to allow him to seek that kind of amusement, which the perusal of romances might afford him; but though he was only 10 years old, he was sensible of the injury produced by this kind of desultory reading; and as soon as he regained his health, he sought a remedy for this evil in the severer studies of mathematics and laborious calculations. After having spent between 3 and 4 years at Eton, he was placed under private tuition for the recovery of his knowledge of the Latin language which he had nearly lost; and in 1638 he accompanied his brother Francis on his foreign travels, under the care of Mr. Marcombes. In their route they passed from Dieppe to Rouen, Paris, and Lyons, and at length settled at Geneva, where they were directed to remain and to pursue their studies. The principal objects of Mr. Boyle's attention were mathematics, in the prosecution of which he found great pleasure; but besides these, he employed himself in the study of rhetoric, logic, and political geography, and in acquiring the external accomplishments of fencing, dancing, &c. At this time some incidents happened, which concurred with his naturally serious disposition to direct his thoughts to the subject of religion; and in examining the evidences of the christian revelation, he obtained full satisfaction, notwithstanding the doubts and difficulties which had occasionally perplexed his mind; and was confirmed in his belief of its truth and importance. Having remained a year and three quarters at Geneva, he left it in September 1641, and traversing various parts of Italy and Lombardy he arrived at Venice; and from Venice he proceeded to Florence, where he spent the winter. During his residence in this city, he acquired a knowledge of the Italian language; and employed a great part of his time in reading modern history; and in acquainting himself with the new discoveries of Galileo, who died in the vicinity of Florence at the period of Mr. Boyle's abode in this city. Towards the end of March, 1642, he commenced his journey to Rome, visiting the most remarkable places in his route thither; and from Rome, where his stay was short, he returned to Florence, and from thence he passed to Leghorn, and afterwards to Genoa. Having travelled through the country of Nice, and crossed the sea to Antibes, he proceeded to Marseilles, where he expected bills of exchange; but, to his great mortification, he found a letter from his father informing him and his brother, that the rebellion had broke out in Ireland, and that it was with considerable difficulty that he had been able to procure for them a remittance of 250l. in order to defray their expences in their return to their own country. But through the negligence of the person, to whom the remittance was entrusted, they received no part of this money, and were, therefore, left in a destitute condition. At Geneva, whither they were enabled to proceed by the assistance of Mr. Marcombes, their governor, they waited two years without receiving any supplies; and by the disposal of some jewels which they took up on his credit, as they proceeded on their journey homeward, their travelling expences were defrayed, and they arrived safe in England about the middle of the year 1644. On their arrival they received the news of their father's death; but Mr. Boyle was amply provided for by the bequest of the manor of Stalbridge in England and other estates in Ireland; and yet on account of the confusion of the times, he was for some months unable to procure any money. However he was relieved on his arrival by his sister the lady Ranelagh; and by her interest, and that of his brother lord Broghill, his English and Irish estates were secured for him. He also obtained leave to go to France; and having settled his accounts with Mr. Marcombes, he soon returned. In March, 1645, he retired to his manor of Stalbridge, and for 5 years devoted himself to various kinds of literary and scientific pursuits in this place; and more particularly to the study of natural philosophy and chemistry. During this period of retirement, when he was about 20 years of age, he commenced that extensive correspondence with the principal persons of his time, which he maintained, with distinguishing reputation to himself and benefit to the world, till near the close of his life. In the list of his first literary friends and correspondents, we may enumerate Mr. Francis Tallents,

afterwards known to the world as the author of the "Chronological Tables;" Mr. Samuel Hartlib, whom he greatly esteemed, and who is mentioned with peculiar commendation by Milton in his "Tractate of Education;" Dr. William Petty; Mr. John Beale, besides many others. At this early age he manifested his zeal for religion, as well as his candour and christian charity, by favouring the designs of Mr. John Drury, for effecting a reconciliation between the Lutherans and Calvinists. He was likewise one of the first members of that learned body, which, after the restoration, was incorporated under the title of the *Royal Society*. Notwithstanding the disease of the stone, with which he was afflicted, and numerous avocations which his various connections imposed upon him, his application to study was assiduous and indefatigable; and before he had attained the age of 20, he had completed three treatises, viz. "Seraphic Love," "Essay on mistaken Modesty," and "the Swearer silenced," or "Free discourse against swearing." Mr. Boyle was distinguished as a promoter of literature and science, by his patronage of others engaged in similar pursuits, as well as by his own labour and writings. Accordingly, in 1651, Dr. Nathaniel Highmore, an eminent physician, dedicated to him his "History of Generation," which was a work at that time much esteemed. Whilst he was unwearied in his chemical and philosophical inquiries and experiments, he was no less attentive to the subject of religion; and with this view he applied to the study of the scriptures in their original languages. About the year 1652 he began his "Essay on Scripture;" and he continued it during frequent interruptions, occasioned by his journies to Ireland at this period. Ireland, however, where he spent a great part of two years, from 1652 to 1654, did not afford favourable opportunity for prosecuting the researches to which he was devoted; and, therefore, he employed the time of his continuance there principally in anatomical dissections, with the assistance of his friend Doctor, (afterwards sir William) Petty. Upon his return to England in 1654, he settled at Oxford, where he had the advantage of pursuing his experiments, and where he enjoyed the society of many learned friends, who occupied different situations in the university. It was during his residence at Oxford, that he invented, or rather improved, the construction of the air-pump (See Air-*pump*); an instrument, by the use of which he was enabled to perform a variety of experiments, relating to the gravity and elasticity, and other qualities of the air, which entitled him to rank amongst the first philosophers of any age. He had at this early period of his scientific career renounced the philosophy of Aristotle, as a system of words instead of things; and attached to the only just and effectual mode of pursuing philosophical researches by experiment, and fearing lest his mind should acquire any improper bias from the ingenuity of the author, he declined the perusal of the works of Des Cartes, whose philosophy was held by many in high estimation. Mr. Boyle did not restrict himself, whilst he continued at Oxford, to the study of philosophy; but he availed himself, in the prosecution of sacred criticism, of the assistance of those great orientalists, Dr. Edward Pococke, Mr. Thomas Hyde, Mr. Samuel Clarke, and Dr. Thomas Barlow, afterwards bishop of Lincoln. His correspondence was also at the same time very extensive; and was carried on for the purpose of the promotion of science with Mr. Henry Oldenburgh, afterwards secretary to the Royal Society, Dr. John Beale, John Evelyn, esq. Dr. John Pett, and Dr. John Wallis, who honoured him with the dedication of his excellent treatise "De Cycloide, et corporibus inde genitis."

In 1659, as soon as he was made acquainted with the distressed circumstances of Dr. Robert Sanderson, afterwards bishop of Lincoln, who had been deprived of his preferments on account of his attachment to the royal cause, he settled upon him an annuity of fifty pounds a year; a favour which was respectfully acknowledged by the doctor in his dedication of "Ten lectures on cases of conscience," delivered in Latin in 1647, and printed at Oxford in 1659.

After the restoration in 1660, Mr. Boyle was treated with great respect by the king, and also by the lord-treasurer, lord Southampton, and lord chancellor Clarendon; and by the latter he was urged to enter into holy orders. Having considered the proposal with due attention, his pious scruples determined him to decline the clerical office. In this year he published his "New experiments touching the spring of the air;" which involved him in a controversy with Franciscus Linus and Mr. Thomas Hobbes, and to which he annexed a defence in the edition of 1662; and also his discourse "On seraphic love." Mr. Boyle's reputation had at this time extended itself to foreign countries; so that the grand duke of Tuscany communicated to him by Mr. Southwell, then resident at Florence, his wish to correspond with him on philosophical subjects. In 1661 he published his "Physiological essays, and other tracts;" and soon afterwards his "Sceptical chemist." Other treatises, to which he refers in this publication, and which were in great forwardness, were unfortunately lost at the time of the great fire of London. In 1662, a grant of the forfeited impropriations in Ireland was obtained from the king in his name, but without his knowledge; and they were applied by him to the promotion of religion and learning. He was also appointed governor of the corporation for propagating the gospel in New England; and in this office he was active and successful in restoring an estate, of which they had been deprived by Col. Bedingfield, a papist, although they had given him for it a valuable consideration. In the conduct of the concerns of this institution he was, in other respects, eminently useful. When the Royal Society was incorporated in 1662, Mr. Boyle was appointed one of the council; and as he may justly be regarded as one of the founders of this society, he continued through life one of its most useful and industrious members. In the following year he published his "Considerations on the usefulness of experimental philosophy;" his "Experiments and considerations upon colours," with "Observations on a diamond that shines in the dark;" and "Considerations on the style of the holy scripture," extracted from a larger work, entitled "An essay on scripture," published after his death by Mr. Peter Pett, attorney-general for Ireland. In 1664, Mr. Boyle was elected into the company of royal miners; this new connection, and other engagements of a benevolent and public nature, prevented his publishing any treatises, either on religion or philosophy, in this year. But the year 1665 produced his "Occasional reflections on several subjects;" to which is prefixed, "A discourse concerning the nature and use of such kind of writings." This piece, which had been written by Mr. Boyle in his youth, and at various intervals, was ludicrously attacked by Dr. Swift in his "Pious meditations upon a broomstick, in the style of the honourable Robert Boyle." How far Mr. Boyle possessed in his youth, or acquired in his maturer years, a correct taste and style of writing, particularly in works of imagination, it is now needless to inquire; it is sufficient to observe, that no attack on the part of Dr. Swift can affect the fame of this distinguished person, either as a man or a philosopher. In this year Mr. Boyle, besides some communications to the Royal Society, printed in the Philosophical Transactions, published "Experiments and observations relative to an experimental history of cold, with several pieces thereunto an-

nexed;" a work well received at the time, and containing a variety of observations and facts that have been useful to those who, in more modern times, have directed their attention to this interesting subject. Towards the close of this year, his majesty appointed Mr. Boyle provost of Eton college; but he declined accepting this honourable and lucrative office, because he did not wish his studies to be interrupted, and because he thought it more suitable to a person in holy orders.

About this time Mr. Valentine Greatraks, an Irish gentleman of good family and competent fortune, and of a serious disposition inclining to melancholy, persuaded himself that he possessed the power of curing diseases by stroaking. In some cases he succeeded, but in others he failed. His performances, however, were so extraordinary, that they excited very general attention; and an account of them was published, by Mr. Henry Stubbs, in a letter entitled "The miraculous conformist, &c." and addressed to Mr. Boyle. To this letter Mr. Boyle replied; but his answer was not published till eighty years afterwards, in Dr. Birch's account of his life. Nevertheless, the sentiments and reflections contained in it were probably communicated to his friends; and though they were expressed with a caution, candour, and judgment, that did him great honour, they were thought to countenance what some persons deemed a deception, or the mere effects of enthusiasm, and they produced a controversy of some continuance. As far as Mr. Boyle was concerned in this business, it will be sufficient to observe, that, firmly believing the actual exercise of those miraculous powers which attested the truth and divine origin of christianity, and admitting, in consequence of the extent and variety of his researches into the operations of nature, the reality of facts, which he could not immediately reconcile by analogy to the small aggregate of human acquisition, the letter, hastily written by him in reply to Mr. Stubbs, did not at all derogate from his character as a philosopher, or as a man of rational piety. He neither denied nor admitted the existence of the miraculous power ascribed to Mr. Greatraks; but allowing the facts, he proposed a variety of inferences and queries, which demanded discussion; and in the whole of this controversy he conducted himself in such a manner as to avoid personal censure from any of the disputants. See Stroaking.

In 1666 Dr. Wallis addressed to Mr. Boyle "An hypothesis about the flux and reflux of the sea," printed in N° xvi. of the Philosophical Transactions; and Dr. Sydenham dedicated to him his "Methodus curandi febres, propriis observationibus superstructa." His own publications in this year were "Hydrostatical paradoxes;" "The origin of forms and qualities, according to the corpuscular philosophy, illustrated by experiments;" and several papers communicated to the Royal Society, and printed in the Philosophical Transactions of that period. In the dispute that occurred in the establishment of the Royal Society between the adherents to the Aristotelian or old philosophy, and the advocates for the new method of philosophising by experiments, Mr. Boyle took a decided part with the latter; but without incurring censure or reproach from the most violent of the opposite party. About this time Mr. Boyle removed to London, where he afterwards resided, very much to the advantage of the Royal Society, which he countenanced by his personal presence and philosophical communications; as well as of the cause of science in general.

In 1669, he published his "Continuation of new experiments touching the weight and spring of the air," to which he annexed "A discourse of the atmospheres of consistent bodies;" and also "A discourse of absolute rest in bodies;" together with other hydrostatical pieces subjoined to his larger works: and in the same year he revised several of his former tracts, which had been translated into Latin for the benefit of foreigners. In the following year appeared his treatise "Of the cosmical qualities of things," containing a variety of interesting facts and observations; and several papers, communicated to the Royal Society. At this time his studies were interrupted by a stroke of the palsy, the effects of which were removed by a strict attention to a proper regimen; so that he soon returned to his labours. In 1671, he published a second volume of "Considerations touching the usefulness of experimental philosophy," and "Tracts of a discovery of the admirable rarefaction of the air, &c.;" and in 1672 appeared his "Essay concerning the origin and virtue of gems," 8vo.; his "Tracts, containing new experiments touching the relation between flame and air, and various other interesting subjects chiefly relating to the statical action of fluids;" and, in the Philosophical Transactions, "Observations on shining flesh," and a paper on the effects of the varying pressure of air. In 1673 he published "Essays on the strange subtlety, great efficacy, and determinate nature, of effluviums;" "Experiments on the weighing and coercion of fire and flame," 8vo.; and "A letter concerning ambergris," communicated to the Royal Society. In 1674 appeared a collection of "Tracts on the saltness of the sea; on a statical hygroscope; on the natural and preternatural state of bodies, and on the positive or privative nature of cold," 8vo.; "The excellency of theology compared with natural philosophy," 8vo.; "Tracts, containing suspicions about the hidden qualities of the air: animadversions upon Hobbes's problem concerning a vacuum; and a discourse of the cause of attraction by suction," 8vo.; and in this year he communicated to the editor of the Philosophical Transactions, "An account of the two sorts of Helmontian laudanum." In 1675 he published "Some considerations about the reconcileableness of reason and religion," by T. E. a layman; to which is annexed, by the publisher, "A discourse of Mr. Boyle about the possibility of the resurrection," 8vo. T. E. are supposed to be the final letters of his own name, as both these tracts are ascribed to him. In this year he communicated to the Royal Society four papers, which appear in the Transactions: "On the air-bladders of fishes;" "A new essay instrument;" "New experiments touching the spring of the air, &c.;" and "An experimental discourse of quicksilver growing hot with gold." In 1676 he published "Experiments and notes about the mechanical origin of particular qualities," in which he treats of alkalis and acids, heat and cold, tastes, odours, volatility, fixity, corrosive action, precipitation, magnetism, and electricity; and he also communicated to the Royal Society two papers on the configuration of the surfaces of fluids in contact with each other.

Mr. Boyle, having been for several years an active and useful director of the East-India company, wished to avail himself of his office for propagating the gospel in those remote parts to which their commerce extended: and with this view he caused 500 copies of the four gospels and acts of the apostles to be printed at Oxford, in the Malayan tongue, under the direction of Dr. Thomas Hyde, and to be sent abroad at his own expence. For similar purposes of piety and benevolence, he had transmitted, about three years before, several copies of Grotius's treatise "De veritate Christianæ religionis," translated into Arabic by Dr. Edward Pococke, into the Levant.

In 1677 a miscellaneous collection of his works, defective, and badly arranged, was printed in Latin at Geneva.

In the following year he communicated to Mr. Hook a "Short memorial of ſome obſervations made upon an artificial ſubſtance that ſhines without any preceding illuſtration," which was publiſhed in that philoſopher's "Cutlerian lectures:" this ſubſtance was the phoſphorus of urine. In this year he alſo publiſhed his "Hiſtorical narrative of a degradation of gold made by an anti-elixir," 4to.; and he received a tribute of ſingular reſpect, in a letter from the great Newton, laying before him his ſentiments concerning an ethereal medium, which he afterwards propoſed, in his Optics, as the mechanical cauſe of gravitation. In the year 1680, he publiſhed "The aerial noctiluca," 8vo.; and "An account of a new lamp," in Hook's Philoſophical Collections; and he improved the ſecond edition of his "Sceptical Chymiſt." Some perſons have very unwarrantably aſſerted, that Mr. Boyle aſſumed to himſelf the invention of phoſphorus, after having purchaſed the ſecret of Kraft. This calumny is refuted by his own narrative, in which he diſcuſſes the claims of Brand, Kunckel, and Kraft, and acknowledges the advantage which he derived, in the proſecution of his inquiries, from the information communicated to him by the latter, that the ſhining ſubſtance was obtained from a matter belonging to the human body. From the narrative it appears, that the aerial noctiluca was an aqueous ſolution, or diffuſion of phoſphorus, obtained by diſtillation from putrid urine in an experiment where his retort failed; and which did not prove altogether ſucceſsful. At the annual election of officers for this year, Mr. Boyle was elected preſident of the Royal Society; but having objections of delicacy with regard to the official oaths that are required, and for ſome other reaſons, he declined accepting the honour. At this time he contributed very liberally to the publication of Burnet's Hiſtory of the Reformation, as the author acknowledges in his preface to the ſecond volume. It was probably about the beginning of the year 1681, that he exerted himſelf for promoting the propagation of the goſpel among the Indians; as his letter on this ſubject was a reply to one from Mr. John Elliot, of New England, dated Nov. 4, 1680. From this letter, which is preſerved by Dr. Birch, it appears that he was a declared enemy to perſecution on account of religious opinions. In this year (1681) he publiſhed his "Diſcourſe of things above reaſon;" and in the following year, "New experiments and obſervations made upon the icy noctiluca," 8vo.; and alſo a "Continuation of new experiments phyſico-mechanical, touching the ſpring and weight of the air, with a large appendix." It appears that his icy noctiluca was the ſolid phoſphorus, which at firſt he found ſome difficulty in making; but from a paper left with the ſecretary of the Royal Society, to be opened after his death, which was nevertheleſs communicated to his friend Dr. Beale during his life, we find that he evaporated urine by diſtillation till it acquired the conſiſtence of ſyrup, then mixed it with ſiliceous ſand, and diſtilled by a ſtrong heat into a reſervoir containing water. See Phosphorus. In 1683 he wrote a letter, ſanctioning and encouraging an undertaking of Mr. Fitzgerald for rendering ſea-water freſh; and in the following year, he publiſhed his "Natural hiſtory of human blood," and his "Experiments and conſiderations about the poroſity of bodies," both in 8vo. From a letter addreſſed to Mr. Boyle in 1684 by the learned Dr. Cudworth, it appears how highly he appreciated his talents and labours. After recommending a collection of his ſeveral treatiſes, he concludes in theſe terms: "You have much outdone Sir Francis Bacon in your natural experiments; and you have not inſinuated any thing, as he is thought to have done, tending to irreligion, but the contrary." The year 1685 produced his "Short memoirs for the natural experimental hiſtory of mineral waters," and an "Eſſay on the great effects of even languid and unheeded motion;" to which is annexed an "Experimental diſcourſe of ſome hitherto little regarded cauſes of the ſalubrity and inſalubrity of the air," 8vo. In the courſe of that year appeared in the Philoſophical Tranſactions, "An account of a ſtrangely ſelf-moving liquor," which was a compound of oils and bitumens, the ingredients of which, though known to himſelf, he has not ſpecified: and alſo a diſtinct treatiſe "On the reconcileableneſs of ſpecific medicines to the corpuſcular philoſophy, to which is annexed, a diſcourſe about the advantages of ſimple medicines," 8vo. Beſides theſe philoſophical tracts, he preſented the world in this year with a theological treatiſe, entitled, "Of the high veneration man's intellect owes to God, particularly for his wiſdom and power," 8vo. The only work that appeared in 1686, was his "Free inquiry into the vulgar and received notion of nature." This treatiſe was much admired by the advocates for pure religion and ſound philoſophy; it was tranſlated into Latin, and reprinted in the following year in 12mo. In this year, 1687, he publiſhed a work, written in his youth, entitled "The martyrdom of Theodora and Dydimia," and five decades of "Choice remedies," to which when the work was reprinted in 1692, five more were added. In 1688 appeared "A diſquiſition about the final cauſes of natural things; wherein it is inquired whether, and if at all, with what caution, a naturaliſt ſhould admit them; to which was ſubjoined, by way of appendix, "Some uncommon obſervations about vitiated ſight." About the beginning of this year our author found it expedient to apprize the public, by way of preface to his mutilated and unfiniſhed writings, and as a general apology for the ſtate in which they appeared, that ſome of his papers had been ſtolen from him, and that others had been deſtroyed by corroſive liquors. The decay of his health, and the derangement of his affairs in Ireland, obliged him to diminiſh the number of his communications to the Royal Society, and induced him to reſign the office of governor of the corporation for propagating the goſpel in New England. From other arrangements with regard to his private affairs, his papers, and the number of viſits which he received, it appeared that he was not without apprehenſions of an approaching change. The time, however, which he thus reſerved to himſelf, he induſtriouſly improved; as he availed himſelf of it for collecting various elaborate proceſſes in chemiſtry; which, as we are informed in a letter preſerved by Dr. Birch, "he left as a kind of hermetic legacy to the ſtudious diſciples of that art." This collection he committed to the care of a friend, enjoining him to impart it to the public faithfully, and without envy, verbatim in his own expreſſions. This friend is unknown, and the work was never publiſhed. From many circumſtances, however, we are led to conclude, that Mr. Boyle concurred, with many other ingenious alchymiſts of the age in which he lived, in believing, what is now rejected as a groundleſs opinion, the poſſibility of tranſmuting the baſer metals into gold; and hence, probably, he was led to take pains in procuring, in 1689, the repeal of the ſtatute of the 5th of Henry IV. againſt the multiplying of gold and ſilver.

In 1690, he publiſhed his "Medicina hydroſtatica, or hydroſtatics applied to the materia medica," 8vo. with the promiſe of a ſecond volume, which never appeared; and "The chriſtian virtuoſo, ſhewing, that by being addicted to experimental philoſophy, a man is rather aſſiſted, than indiſpoſed to be a good chriſtian;" a ſecond part of which was publiſhed in an imperfect ſtate, after his death. In 1691, he communicated to M. de la Croze, "An account of ſome

observations made in the great congregation of waters, by lowering down bottles into the sea 600 feet from the surface," which was printed by that author in the "History of learning." Mr. Boyle's last work, published by himself, was his "Experimenta et observationes physicæ;" to which is added "A small collection of strange reports," 8vo.

In July of this year, Mr. Boyle executed his last will, and in the succeeding months his health rapidly declined. On the 23d of December, he lost his sister, lady Ranelagh, to whom he was affectionately attached, and within a week afterwards, viz. on the 30th of December, 1691, he departed this life, in the 65th year of his age, and was interred at the upper end of the south side of the chancel of St. Martin's in the fields, near the remains of his sister, with whom he had lived for the greatest part of 47 years. His funeral sermon was preached by Dr. Burnet, bishop of Salisbury.

Mr. Boyle's posthumous works are as follow: 1. "The general history of the air, designed and begun," 1692, 4to.; 2. "Medicinal experiments, or a collection of choice remedies, for the most part simple, and easily prepared," 1692, 12mo; 3. "General heads for the natural history of a country, great or small, drawn out for the use of travellers and navigators," 1692, 12mo.; 4. "A paper of the honourable Robert Boyle's, deposited with the secretaries of the Royal Society, Oct. 14, 1680, and opened since his death; being an account of his making the phosphorus, &c. Sept. 30, 1680;" 5. "An account of a way of examining waters, as to freshness or saltness;" 6. "A free discourse against customary swearing, and a dissuasive from cursing;" 1695, 8vo. 7. "Medicinal experiments, or a collection of choice remedies, chiefly simple and easily prepared, used in families, and fit for the service of the country people;" the 3d and last volume published from the author's original MSS. A collection of all Mr. Boyle's works was published in 1744, in 6 volumes folio, with a life prefixed, by Dr. Birch; and in 6 vols. 4to. in 1772.

Mr. Boyle, as to his person, was tall and slender, and of a pale and emaciated countenance. His constitution was so delicate, that he regulated his cloathing by a thermometer: and he was occasionally subject to such debility of body, such painful paroxysms of the stone, and such depression of spirits, that we may be well astonished at the number and variety of his scientific and literary performances. However, to the simplicity of his diet, and the strict temperance which he observed, we may reasonably ascribe the degree of health which he enjoyed, and the length to which his life was protracted. His speech was slow and deliberate, and subject to hesitation; in his conversation he was unassuming, never dictating his own opinions, or urging his objections to those of others with confidence, but rather proposing them as topics of inquiry and discussion; and in his manners he was singularly mild and courteous. Although he was a favourite at court, and indulged in free intercourse with three successive sovereigns, viz. Charles II. James II. and William III., he never disguised his sentiments with regard to public men and measures; but he took no active part in the politics of the eventful times in which he lived, preferring the pursuits of philosophy, and the retirement which best suited his infirm frame and religious temper. To the rank of a peerage he never aspired, but refused it whenever it was offered to him. One of the most prominent features of his character, was his sincere and unaffected piety. This was exemplified in all his writings, and in the whole course of his life. Of his firm attachment to Christianity, and of his solicitude for vindicating its truth, and extending the knowledge and influence of it, he exhibited many substantial proofs, both whilst he lived, and at his death. Besides the translation of the gospels and book of acts into the Malayan language, and of Grotius's treatise concerning the truth of the Christian religion into Arabic, which we have already mentioned, and which was conducted at his own expence, he proposed an impression of the New Testament in the Turkish language; and when the Turkey company undertook it, he liberally contributed towards accomplishing it. A translation and edition of the Bible in the Irish language cost him 700l.; and he defrayed a considerable part of the charge attending an impression of the Welsh Bible, and of the Irish Bible for Scotland. He gave, during his life 300l. towards propagating the Christian religion in America; and as soon as he heard that the East India company were projecting a similar design in the East, he sent a donation of 100l. by way of example and encouragement in the prosecution of the scheme. Of the impropriations belonging to his estates he ordered considerable sums to be given to the incumbents in these parishes, and even to the widows of those who had died before this distribution of his bounty. This he did twice during his life to the amount of 600l., and he ordered another distribution as far as his estate would bear, by his will. In other respects, his charities were so numerous and extensive, that they amounted, as bishop Burnet informs us, from his own knowledge, to upwards of 1000l. per annum. The annuity established by his will for providing a series of lectures in defence of Christianity, affords further evidence of the benevolence of his temper, and of his concern for promoting the interests of religion. See BOYLE's *Lectures*. His zeal in the cause of religion, though it was ardent and active, was free from the least tincture of bigotry and intolerance. Whilst he adhered to the established church, he entertained the most undissembled charity towards all who differed from him in opinion: nor did he ever express himself in stronger terms, and with a greater degree of indignation, than when he condemned every kind of severity and persecution in the province of religion. Burnet in his funeral eulogy informs us, that his knowledge comprehended Hebrew and the other Oriental languages, the writings of the most eminent fathers, commentaries on the scriptures, religious controversies, and the whole body of divinity. He represents him as being acquainted with the whole compass of the mathematical sciences, and as well versed even in the most abstruse parts of geometry. Geography, navigation, and books of travels he had recourse to for the relaxation of his mind, and the amusement of his intervals of leisure. Of his knowledge with regard to subjects of natural history, chemistry, and experimental philosophy, his various researches and discoveries, recorded in his numerous publications already recited, afford ample evidence. Mr. Boyle, indeed, possessed in an eminent degree those qualities, which justify his being ranked among the first philosophers of any age or country. He was distinguished by the comprehension of his views, and the extent and variety of his researches, by indefatigable diligence and invincible perseverance in his collection of facts and investigation of their causes, by a total freedom from any preconceived attachment to theories and systems, by candour in discussing the opinions of others, and by fidelity, modesty and perspicuity in the narration of his own performances. Mr. John Hughes might well say of him (Spectator N° 554), after observing that he was born the same year in which lord Bacon died, that he was the person designed by nature to succeed to the labours and inquiries of that extraordinary genius. It would be endless to recount the testimonies in commendation of him, that

might be collected from the writings of the most illustrious foreigners, and of the best judges of his merit in our own country. It will be sufficient to say, that he is uniformly ranked with Bacon and Newton; that his researches and experiments have led the way to many modern discoveries both in philosophy and chemistry: and that his writings will ever be held in high estimation by every friend of science. "They cannot be read," says one of his biographers, "without improvement; and in these alone, if no life of Boyle had ever been written, the reader would behold a man truly deserving of the affection, the esteem, and the admiration of succeeding ages." Boyle's account of himself, under the name of Philocetus. Birch's life of Boyle, prefixed to his works. Burnet's funeral sermon. Biog. Brit. Birch's Hist. of the Royal Society. Phil. Trans.

Brass

BRASS, or Latten, *Laiton Jaune*, Fr.; *Messing* G. This very important alloy is a mixture of copper and zinc in various and uncertain proportions, so intimately united as to form a homogeneous malleable yellow metal, applicable to a vast variety of purposes in the arts, and capable of being wrought in various ways with the greatest facility.

Mere fusion will scarcely produce a perfect union between copper and zinc; for the latter metal, being highly volatile and combustible, readily takes fire, and burns off at a heat necessary to melt the copper; and hence, when the metals are simply melted together, before an uniform alloy can be obtained, the proportion of zinc is every moment lessening by its volatilization, and would continue to fly off in this manner, by the continuance of the fusion, till at last scarcely any thing but the copper would be left behind. In order, therefore, to combine copper with as much zinc as it can take up, so as to retain its malleability, the very ingenious process of *dry cementation* has been resorted to in the manufacture of brass, which is performed by strongly heating small pieces of copper in close vessels with zinc in the state nearly of vapour, whereby it is thoroughly penetrated with the zinc, and unites with it into a perfect alloy.

Zinc being a volatile metal, it can only be procured from its ores by sublimation; and the process of obtaining it (which will be described at length under that article), is to heat strongly a mixture of the native oxyd with charcoal in a close vessel, with no other exit for the vapour than a tube dipping its further end in water. As soon as the charcoal reduces the oxyd to the metallic state, the zinc rises in vapour, passes through the tube, and is condensed in the water. A similar reduction takes place in brass-making, only, instead of conveying the vapour of the zinc out of the crucible, in which it is formed, copper is inclosed in the same vessel, which being then thoroughly heated, readily absorbs the zinc as soon as reduced to the metallic state, fixes it, contracts a very intimate union with it, and the result is perfect brass.

Brass is made in many countries, but no where more extensively and better than in England, in which both the materials are in great abundance. The ores of zinc are several species of *calamine*, and of *blende* termed by the miners *black jack*, which are found abundantly in Devonshire, Derbyshire, and North Wales, accompanying the lead ores, and in other places. These are chiefly oxyds or carbonated oxyds of zinc, and require a previous calcination before they are fit for brass-making. At Holywell, in Flintshire, the calamine, which is received raw from the mines in the neighbourhood, is first pounded in a stamping mill, and then washed and sifted, in order to separate the lead with which it is largely admixed. It is then calcined on a broad shallow brick hearth, over an oven heated to redness, and frequently stirred for some hours; or, in some places, a conical pile is composed of horizontal layers of calamine alternating with layers of charcoal, and the lowest layer is of wood in large pieces, with intervals left for the draught of air through the centre of the pile, to maintain the combustion thoroughly.

The calamine being fully calcined is then ground in a mill, and mixed at the same time with about a third or fourth part of charcoal, or in some places with pit-coal, which last, however, injures the malleability of the brass. This mixture is then put into large cylindrical crucibles, along with alternate layers of small bits of copper, consisting either of the clippings of copper plates, or of copper shot, made by melting any refuse pieces of this metal, and pouring it into

cold water, which divides it into very ſmall rounded ſhot-like fragments. Powdered charcoal is put over all, and the crucibles are covered and luted up. The braſs furnace has the form of the fruſtum of a hollow cone, or a cone with the baſe downwards, and the apex cut off horizontally. At the bottom of the furnace is a circular grate, or perforated iron plate, coated with clay and horſe-dung, to defend it from the action of the fire. The crucibles ſtand upon the circular plate, forming a circular row with one in the middle. The fuel, which in England is coal, is thrown round the crucibles, and is thrown into the furnace at the upper part of it, or the truncated apex of the cone. A perforated cover, made of bricks or clay, and kept together by iron bars, is fitted to this opening. This cover ſerves as a regiſter to regulate the heat; ſo that when it is to be increaſed, the cover is to be partly or entirely removed, and a free draught admitted to the external air, which paſſes along an underground vault to the aſh-hole, through the holes in the circular grate betwixt the crucibles, and through the upper mouth, along with the ſmoke and flame, into an area, where the workmen ſtand, which is covered by a large dome with a chimney to conduct the ſmoke out of doors. To diminiſh the heat, the regiſter cover is put on the mouth of the furnace, leaving thereby no other exit for the ſmoke and flame than the holes of the cover. The time requiſite for heating the crucibles varies conſiderably in different works, being determined chiefly by the nature of the calamine or other ore of zinc employed, and alſo by the ſize of the crucibles. In the great way, at leaſt ten or twelve hours are required. At Holywell about twenty hours are employed.

During the proceſs, and eſpecially towards the latter end, part of the reduced zinc which eſcapes, being abſorbed by the copper, finds its way in vapour through the crucible lids, and burns around them with the beautiful blue flame and white ſmoke peculiar to this volatile metal.

The heat required for braſs-making is ſomewhat leſs than what is neceſſary to melt copper, for braſs is more fuſible than copper, and the zinc is able to penetrate copper when kept at a full red heat. When the braſs is judged to be made, the heat is increaſed to fuſe the whole down into one maſs at the bottom, and the crucibles are then removed, and the melted braſs poured out into moulds. At Holywell, ſix crucibles are uſed to one furnace; and the quantity of braſs procured from them all is ſufficient to fill one of them. This makes a ſingle large braſs plate, which is manufactured in the ſame way as copper plate. Or, more accurately, from forty pounds of copper and ſixty pounds of calamine, about ſixty pounds of braſs are obtained, beſides that a conſiderable quantity of zinc burns off in the proceſs above-mentioned.

The above is the uſual proceſs of making braſs in moſt parts of England, and is eſſentially the ſame wherever this alloy is manufactured, but with ſome variation as to the choice of ingredients, their proportions, the time of fuſion, and other ſmaller circumſtances. In Goſlar in Saxony, inſtead of a native calamine, the *cadmia*, or ſublimed oxyd of zinc is uſed, which is collected in a particular part of the chimnies of the reverberatory furnaces, in which the lead ores and blendes are roaſted. The proportions of the ingredients alſo vary conſiderably. According to Swedenborg, they are, in Goſlar, 30 parts of copper, 40 to 45 of cadmia, and twice the volume of charcoal; in many of the manufactories in France, 35 of copper, 35 of old braſs, 40 of calamine, and 20 to 25 of charcoal; in Sweden, 30 of copper, 20 to 30 of old braſs, and 46 of calamine, with charcoal ſufficient; or 40 of copper, 30 of old braſs, and 60 of calamine; in this country, generally about 40 of copper, and 60 of calamine. The product of braſs varies alſo; but it ſeems to be in few places ſo great as in ſome of the works of England, where, as already mentioned, 40 pounds of copper increaſe to 60 pounds of braſs. This ſuperior quantity is aſcribed to the ſmallneſs to which the copper is previouſly reduced by pouring it melted into water, which, it ſeems, is not always practiſed elſewhere, and probably too to the goodneſs of the calamine.

At Stolberg, near Aix la Chapelle, where braſs is made to a very great extent, the furnaces are cylindrical, and each contains eight crucibles arranged in two tiers of four each. The crucibles are fifteen inches high, twelve inches deep, and eight or nine wide. The proportions are 40 pounds of copper, 65 of calamine, and double its volume of charcoal. After the fire has been kept up for twelve hours, a workman takes off with an iron trowel all the ſcum and charcoal which ſwim upon the liquid, and when cooled form a maſs called *arkeſt*. This, examined by a glaſs, is found to conſiſt of calamine and copper particles cohering together, but not completely united. The braſs reſulting from this firſt proceſs is coarſe, brittle, and unequal in texture, and requires a ſecond fuſion, before it is fit to be wrought. For this purpoſe the ſame crucibles are again employed, and are filled, firſt with three handfuls of the mixture of calamine and charcoal, over which are put two or three pounds of the impure braſs broken in pieces, then more calamine and charcoal, with a piece of the *arkeſt*, and over all the calamine and charcoal powder. They are then heated ſtrongly for two hours, after which the braſs is fit to be caſt into plates.

A ſingle fuſion, where the fire is kept up long enough, and the materials are good, is certainly ſufficient to make good malleable braſs; but it is probable, that the fineſt ſorts undergo a ſecond operation with freſh calamine and charcoal. Some ſecrecy is, however, obſerved by thoſe individuals who have the reputation of making the very fineſt article.

In the laboratory, by way of experiment, braſs may be made in a much ſhorter time by uſing the ſame materials, that is to ſay, copper-ſhot buried in a mixture of calamine and charcoal, putting the crucible in a wind furnace, and heating ſlowly for half an hour, till the zinc begins to burn off in blue flame round the cover of the crucible, and then raiſing the fire, and heating briſkly for an hour longer. This proceſs of cementation of copper is alſo ſhewn very neatly by a ſomewhat different management, as given by Cramer. Put the mixture of calamine and charcoal into a crucible; cover it with a thin layer of clay, over which, when dry, lay a thin plate of copper, and cover the whole with fine charcoal powder, and a luted cover to the crucible. Apply heat gradually, and the vapour of the reduced zinc will riſe through the floor of clay, will penetrate the red-hot copper above it, and convert it gradually into braſs, which, at the end of the operation, will be found lying melted upon the ſtratum of clay; and the increaſe of weight, which the copper will be found thus to have gained, will afford a good practical teſt of the goodneſs of the calamine, and its fitneſs for braſs-making in the great way.

Braſs is wrought into plates by caſting and laminating. At Stolberg the plates are firſt caſt into a mould formed of two blocks of hard granite five feet long, three and a half broad, and eight inches thick. Theſe are placed one above the other, and the upper one is raiſed by a pulley, and ſmeared with cow-dung previous to caſting. To give the plate the requiſite thickneſs, hoops of iron of different dimenſions are adapted to the under ſtone, ſo as to confine the melted metal, and regulate its thickneſs. The ſtones

are gently inclined before the metal is run into them. These plates are afterwards laminated and manufactured in a thousand different ways.

The most important properties of brass, compared with copper, are the following: its colour is much brighter, and more approaching to gold; it is more fusible than copper, as is seen from the circumstance, that less than a copper-melting heat is sufficient for the making of brass; it is less subject to rust, and to be acted on by the vast variety of substances which corrode copper; and lastly, it is equally malleable when cold, and more extensible than either copper or iron; and hence is peculiarly fitted to be made into wire. Brass, however, is only malleable when cold. By hammering, brass is found to become magnetic, perhaps only from the particles of the iron hammer which may have been beaten into its surface; but this makes it necessary to use unhammered brass about compass-needles, and similar magnetic apparatus. The expansion of brass has been very accurately determined, as this metal is most commonly used for mathematical and astronomical instruments, where the utmost precision is required. Mr. Smeaton found that 12 inches in length of cast brass at 32°, expanded by 180° of heat, (or at the boiling point of water,) 225 ten thousandth parts of an inch: brass wire in the same circumstances expanded 232 parts; brass 16 parts, with one of tin, expanded 229 parts. The expansion of hammered copper is only 204 parts, but that of zinc is 353; so that brass holds a middle place in this respect between its two component metals.

The zinc is readily separated from brass by fire. When brass is heated strongly in open vessels to at least a copper-melting heat, the zinc of the brass takes fire, and slowly burns away. If this is continued long enough, little else is left but copper, though still retaining a small portion of zinc, which no further continuance of the heat will entirely separate.

Some kinds of very fine brass, it is said, are not made by cementation in the way already described, but by a more speedy and direct union of copper and zinc, care being taken to prevent the access of air to the materials while in fusion. Very fine brass may also be made in the small way, (and doubtless also in manufacture,) by mixing the oxyds of copper and zinc, and reducing them together. This plan is ingenious, and the intimate mixture of the two metals, the great object in brass-making, is probably more accurately obtained in this way than even by the common process of cementation. The following experiment on this plan is given by Sage: Mix together 50 parts of oxyd of copper, remaining after the distillation of verdigris (which is a very pure oxyd) with 100 parts of lapis calaminaris, 400 parts of black flux, and 30 parts of charcoal powder; melt together, till no longer any blue flame is seen to burn round the top of the crucible. When cold, a fine button of brass is found beneath the scoria, weighing a sixth more than the copper obtainable from the oxyd of this metal reduced in the same way, but without the calamine. This brass has a very fine colour, like gold. On this experiment M. Sage observes, that a sixth increase of weight gained by the copper, is the proportion which constitutes the finest brass, and that which copper will always retain, however long kept in fusion, provided the access of air is prevented, as in this case, by the alkaline scoria. When the copper retains a fifth of zinc, the colour is not so fine; and any quantity above a sixth will be expelled by the heat, even when the alloy is covered; and, on coming to the air, the zinc will burn. Hence the cessation of the zinc flame is in this experiment the proof, that the copper now retains no more than a sixth of zinc, and is fine brass.

The analysis of brass is a point of some consequence, and several modes have been proposed, some good, others defective.

Brass may, in some degree, be analysed by strongly heating in an open vessel, as above mentioned. The zinc then burns off, and when no more flame is given out, the copper is supposed to be pure. But Dizé has found that this mode is very uncertain; so that no two assays of the same sample correspond, for it is not easy to tell when all the zinc is burnt off that can thus be volatilized; and the increase of weight, caused by the oxidation of part of the copper, throws a further uncertainty on this method.

Neither will a simple solution of brass in the sulphuric, or any other acid, and crystallization, answer the purpose; for, though much of the crystallized sulphat of copper may readily be picked out from the sulphat of zinc, the perfect separation of the two kinds of crystals is impracticable, and at last one species becomes mixed with a portion of the other, even in the respective crystals.

M. Dizé proposes the following methods:

1. Dissolve the brass in nitric acid, which takes up the copper and zinc, and leaves any tin with which it is often alloyed. Decompose the clear nitrated solution by pot-ash, redissolve the precipitate in sulphuric acid, and add a piece of clean bright iron to the solution, previously diluted with six parts of water. The copper is thus precipitated in the metallic state, and the solution now holds sulphat of iron, and sulphat of zinc. These M. Dizé proposes to separate by gallic acid, which slowly precipitates the iron, and leaves the zinc. Lastly, the sulphat of zinc may be decomposed by a carbonated alkali, and the quantity of zinc in the carbonat may be estimated according to proportions, which will be presently mentioned.

This method is useful, but the separation of the iron from the zinc by the gallic acid, is excessively tedious. Sulphuretted hydrogen gas would be much shorter, and to be preferred.

2. Dissolve brass in nitric acid, dilute with six parts of pure water, and immerse in the solution a cylinder of bright clean lead. The copper speedily separates in the metallic state round the lead, which last takes its place in the solution. As this advances, the liquor loses its blue colour; and when all the copper is separated, it becomes slightly yellow. To determine, however, whether all the copper is separated, add a fresh clean piece of lead, and boil the solution for some time. This now contains nitrat of lead, and nitrat of zinc. Sulphuric acid will precipitate thence the lead in the form of an insoluble sulphat, and the nitrated zinc may then be decomposed by a carbonated alkali. On this precipitation, however, there are some observations to be made. Copper, when dissolving in nitric acid, absorbs nearly $\frac{40}{100}$ of its weight of oxygen; but lead, under the same circumstances, absorbs only $\frac{16}{100}$. Hence (as Vauquelin remarks on this subject of the analysis of brass) 100 parts of copper dissolved in nitric acid would require, for their disoxygenation, (which takes place whenever one metallic oxyd in solution is precipitated in a metallic form by another metal immersed in it,) full 250 parts of lead, which last is of course oxidated in proportion as the copper precipitates in the metallic form. But this large quantity of oxyd of lead cannot be held in solution by the nitric acid, except this is largely in excess; and this explains why, as M. Dizé has observed, a portion of oxyd of lead is apt to form at the latter end of the process, and to mix with the copper, so as to require a subsequent operation to get the copper free from it. Nor will an excess of acid ensure the purity of the precipitated copper; for M. Vauquelin finds that

if 50 grains of pure copper are diffolved in nitric acid to excefs, and then precipitated by metallic lead, of which about 220 grains are requifite, the cupreous precipitate weighs 138 grains inftead of the original 50 grains, and therefore is not pure copper, but an alloy of this metal, with a very large proportion of lead. This method, therefore, of analyfing brafs is highly erroneous, unlefs the fuppofed copper precipitate be feparately treated, in order to free it from the large proportion of lead with which it muft be alloyed.

The following methods are given by Vauquelin:

3. Diffolve a given quantity of brafs in nitric acid, put it in a well-clofed bottle, and add cauftic pot-afh to excefs, fo that there fhall be a fenfible alkaline tafte in the liquor; fhake the mixture well, and keep it a fhort time in digeftion. By this fimple procefs the oxyd of copper is precipitated by the alkali, but the oxyd of zinc is re-diffolved in it; and if the liquor be now filtered, the alkaline folution of zinc paffes through clear, and the oxyd of copper is left behind. This oxyd is brown, and nearly metallic in appearance. When thoroughly wafhed, and gently dried, it contains 65 per cent. of metallic copper. If one is affured by a previous affay, that the brafs only contained copper and zinc, when the quantity of copper is thus obtained, that of the zinc may be inferred from the difference between the copper, and the weight of the brafs employed; or elfe the alkaline folution of zinc may be fuperfaturated with fulphuric acid, fo as at firft to precipitate, and afterwards to re-diffolve the zinc, after which this metal may be precipitated as a carbonat, by adding carbonat of pot-afh or foda. A very trifling quantity of copper paffes into the alkaline folution of the zinc, occafioned by a fmall portion of ammonia formed by the nitrated metals when the cauftic alkali is added, which takes up this atom of copper. If neceffary, the copper might be again precipitated by heating the alkaline folution, fo as to expel the ammoniac; but not to boiling, otherwife fome of the zinc would feparate from the alkali, and caufe a greater error.

4. *Diffolve* brafs in fulphuric acid, dilute with 20 times as much water, and immerfe a ftick of zinc exactly weighed. The copper foon precipitates completely in the metallic ftate, which is to be well wafhed and weighed. The folution now contains only the zinc of the brafs, and the zinc diffolved out of the ftick of metal immerfed. By weighing the undiffolved ftick of zinc, and precipitating the whole by carbonat of pot-afh or foda, an eafy calculation will give the portion of zinc belonging to the brafs: or, more fimply, this may be inferred from the copper obtained, and the quantity of brafs originally employed.

It only remains, on the fubject of analyfis, to give the metallic contents of carbonat of zinc. Dizé diffolved 100 parts of zinc in nitric acid, precipitated it by carbonated foda, and this product, well wafhed and dried, now weighed 180 parts. Hence 100 parts of carbonat of zinc thus obtained, contain 55.5 of metallic zinc.

On the other hand, Vauquelin found that carbonat of zinc obtained from the fulphat by carbonated pot-afh, well wafhed and calcined in a crucible to expel all the carbonic acid, contained 69 per cent. of metallic zinc. Hence the carbonat obtained by Dizé, it is obvious, muft only have been dried at a low temperature, probably that of boiling water; and from either of the above data the quantity of zinc may be eftimated: or elfe the carbonat or oxyd may be mixed with charcoal, and ftrongly heated in an earthen retort, without the accefs of external air, by which the zinc will be reduced, and will diftil over, and condenfe in the cool neck of the retort in the metallic ftate.

Analyfis fhews a vaft variety in the proportions of the different fpecies of brafs ufed in commerce; nor is it eafy to determine whether the perfection of this alloy depends on any certain proportion of the two metals, or the mode of manufacture. In general, the extremes of the higheft and loweft proportion of zinc are from 12 to 25 parts in the hundred. Even with fo great a quantity of zinc as 25 per cent., the ductility of brafs is not injured, provided it be manufactured with care, though zinc itfelf is fcarcely malleable. In proof of this, Dizé analyfed a fpecimen of a remarkably fine brafs, which is made at Geneva for efcapement wheels, and other nicer parts of watch-making. This metal unites great beauty of colour to a high degree of ductility; and the bars that are perfect fetch a very high price with the watch-makers of this town, fo celebrated for this delicate manufacture. This brafs was found to confift of 75 of copper, and 25 of zinc. Probably, too, the copper was Swedifh, or of fome other very fuperior kind. The common brafs of Paris appears to contain no more than about 13 per cent. of zinc. The Englifh, probably, contains more zinc.

The ufe of brafs is of very confiderable antiquity; but from the inaccuracy of the ancient defcriptions, and their ignorance of the true nature of zinc and its ores, much uncertainty prevails on this fubject. Moft of the genuine relics of antiquity of this kind are compofed of various mixtures of brafs, with tin and other metals, and are rather to be termed *bronzes*. For this and the other yellow alloys of copper, fee Copper.

Keir, in a note to the article brafs in Macquer's dictionary; Watfon's Effays; Sage in J. Phyf. vol. xxxviiii.; Dizé in ditto, vol. xlviii.; Repertory, vol. xiv.; Vauquelin in An. Ch. vol. xxviii.; Encycl. Meth.; Original, &c.

Brass, in *Antiquity*. See Æs.

Brass, in a more extenfive fenfe, includes copper, and all the mixtures or alloys of copper with other minerals. In which fenfe, brafs amounts nearly to the fame with the Roman æs, and the French *airain*.

Brass-*lumps*, or Brasses, in *Mineralogy*, a common name among the colliers for the maffes of pyrites that are found to accompany, more or lefs, the different kinds of coal.

Brewing

BREWING, *Braſſage de la biere*, Fr. *Das Brauen*, Germ. The art of brewing, or of preparing a vinous fermented liquor from the farinaceous ſeeds, is of very high antiquity. The ancient Egyptians, from the ſoil and climate of their country not being favourable to the culture of the vine, were induced to ſeek a ſubſtitute in barley, from which, in all probability, by the proceſs of malting, they knew how to procure a fermented liquor. The town of Peluſium, ſituated on one of the mouths of the Nile, was particularly celebrated for its manufactories of malt liquor, of which there were two kinds; one called *Carmi* was ſweet, and appears to have reſembled our ſweet and glutinous ales, the other named *Zithum*, ſeems to have been analogous to modern beer. The Germans, from the teſtimony of Tacitus, were capable of preparing a liquor ſimilar to wine (quandam vini ſpeciem) from barley, by fermentation. Julian, Strabo, and Polybius, ſhow, that the ſame art was

was known to the Spaniards, the Gauls, and the inhabitants of the British islands, and the north of Europe. All the ancient malt liquors, however, seem to have been made entirely of barley, or some other farinaceous grain, and therefore were not generally calculated for long keeping, as this quality depends considerably, though not entirely, on the bitter extract of hops, or other vegetables, with which the liquor is mingled.

Modern malt liquor is essentially composed of water, of the soluble parts of malt and hops, and of yeast.

For a particular account of the preparation of MALT, we refer our readers to that article. It will be sufficient for our present purpose, to mention, that barley consists of fecula or starch, albumen, and a little gluten; and, that by the process of germination or malting, the starch is converted into saccharine mucilage. If each grain of barley was perfectly malted, the whole of its starch would be changed into sugar; this, however, is never the case: the soluble contents, therefore, of such malt as the brewers make use of, arranged in the order of their respective proportions, are saccharine mucilage, starch, albumen, and gluten, of which only the first is absolutely necessary for the production of a vinous liquor. Three or four different kinds of malt are distinguished by the brewer by their colours, which depend on the degree of heat that was used in the drying. Malt that has been dried by a very gentle heat scarcely differs in its colour from barley; if exposed to a somewhat higher temperature, it acquires a light amber-yellow hue; and by successive increments of heat, the colour becomes deeper and deeper, till, at length, it is black. The change of colour is owing to the grain being partially charred or decomposed; and in proportion to the extent to which this alteration is allowed to proceed, will the produce of sugar, that is of fermentable matter, be diminished. The principal advantage of high-dried malt over the paler kind, is the deep yellowish brown tinge which it gives to the liquor: but this colour may be communicated much more economically by burnt sugar. The malt, whether pale or high-dried, must be bruised between rollers, or coarsely ground in a mill before it is used, and it is found by experience, that malt which has lain to cool for some weeks is, in many respects, preferable to that which is used as it comes hot from the mill. The first step in the process of brewing, is

§ 1. *Mashing.*

This is performed in the *mash-tun*, which is a circular wooden vessel, shallow in proportion to its extent, and furnished with a false bottom, pierced with small holes, fixed a few inches above the real bottom: when it is small, it ought to have a moveable wooden cover. There are two side-openings in the interval between the real and false bottom; to one is fixed a pipe for the purpose of conveying water into the tun; the other is fitted with a spiggot for the purpose of drawing the liquor out of the tun. The brewing commences by strewing the grist or bruised malt evenly over the false bottom of the mash-tun, and then, by means of the side pipe, letting in from the upper copper the proper quantity of hot water. The water first fills the interval between the two bottoms, then forcing its way through the holes in the false bottom, it soaks into the grist, which, at first floating on the surface of the water, is thus raised off the bottom on which it was spread. When the whole of the water is let in, the process of mashing, properly so called, begins. The object in mashing is to effect a perfect mixture of the malt with the water, in order that all the soluble parts may be extracted by this fluid: for this purpose, the grist is first incorporated with the water by means of iron rakes, and then the mass is beaten and agitated, and still further mixed by long flat wooden poles, resembling *oars*, which indeed is the name by which they are technically known. In some of the large porter breweries, the extent of the tun is so great, that the process of mashing cannot be adequately performed by human labour, and recourse is had to a very simple and effectual instrument for this purpose. A very strong iron screw, of the same height as the mash-tun, is fixed in the centre of this vessel, from which proceed two great arms or radii, also of iron, and beset with vertical iron teeth a few inches asunder, in the manner of a double comb: by means of a steam engine, or any other moving power, the iron arms which at first rest on the false bottom, are made slowly to revolve upon the central screw, in consequence of which, in proportion as they revolve, they also ascend through the contents of the tun to the surface; then, inverting the circular motion, they descend again in the course of a few revolutions to the bottom. These alternate motions are continued till the grist and water are thoroughly incorporated. When the mashing is completed, the tun is covered in to prevent the escape of the heat, and the whole is suffered to remain still, in order that the insoluble parts may separate from the liquor: the side spiggot is then withdrawn, and the clear wort is allowed to run off, slowly at first, but more rapidly as it becomes fine, into the lower or boiling copper.

The operation of mashing, as it is the first in order, is the most important; and all the succeeding ones are modified according to the circumstances, under which this primary one is effected. The principal thing to be attended to, is the temperature of the mash, which depends, partly on the heat of the water, and partly on the state of the malt. If any quantity of barley is mingled with twice its bulk of water, the temperature of the mass will be very nearly that of the mean temperature of the ingredients. If the palest malt is subjected to the same experiment, the temperature will be somewhat greater than that of the mean heat. This excess is found to increase very rapidly, in proportion to the colour or dryness of the malt employed; so that when one part of the highest dried malt is mixed with two parts of warm water, the temperature will be no less than 40° Fah. above the mean. In calculating, therefore, the heat of the mash, it is necessary to take into consideration, both the dryness of the malt, and the proportion which it contains of unmalted, or imperfectly malted barley. The object in mashing is to extract from the malt, as much as possible of the saccharine mucilage; but this is so intimately combined with the other parts of the grain, that the range of temperature which can be employed for this purpose, is very confined. If the water was let upon the grist boiling hot, the starch which it contains would not only be dissolved, but converted into a gelatinous substance, in which all the other parts of the malt, and most of the water, would be entangled, beyond the possibility of recovery by any after-process; and great loss is perpetually sustained by inattentive brewers, from this very circumstance. The most eligible temperature upon the whole for mashing, appears to be about 185° to 190° of Fahrenheit: the heat of the water, therefore, for the first mashing, must be somewhat below this temperature, and the lower in proportion to the dark colour of the malt made use of. Thus, for pale malt, the water of the mash may be at 180° and upwards; but for high-dried brown malt, it ought not much to exceed 170°. The wort of the first mashing is always by much the richest in saccharine matter; but to exhaust the malt, a second and third mashing is required; and as no heat is generated, except in the first mashing, the water in the succeeding ones may

may be safely raised to nearly 190°. The proportion of wort to be obtained from each bushel of malt, depends entirely on the proposed strength of the liquor. For sound small beer, 30 gallons of wort may be taken from each bushel of malt; but for the strongest ale, only the produce of the first mashing, or about $6\frac{1}{2}$ gallons per bushel, is employed. But whatever be the proportion of wort required, it must be held in mind, that every bushel of well made malt will absorb, and retain $3\frac{1}{4}$ gallons of water, and therefore the water made use of must exceed the wort required, in the same proportion.

It is of great importance to the brewer, to ascertain the strength of his worts, or their richness in saccharine matter; this may be done, partly by the taste, but more accurately by an instrument called a *Saccharometer*, which in fact is only a hydrometer, the scale of which is adapted to the various densities of wort. The name Saccharometer, however, is an improper one, as it is apt to mislead the brewer: this instrument shews merely the specific gravity of the liquor, and this depends, not only upon the sugar, but the starch, and every other part of the malt which is soluble in water. But the relative proportions of these substances are, in all likelihood, very various in different parcels of malt; whence arises a serious objection to much dependence on the saccharometer.

§ 2. *Boiling and hopping.*

If only one kind of liquor (whether ale or beer) is to be made, the produce of the three mashings is to be mixed together: but, if both ale and beer are required, the wort of the first, or of the first and second mashings, is appropriated to the ale, and the remainder is set aside for the beer. All the wort destined for the same liquor, after it has run from the mash-tun, is transferred to the large lower copper, and mixed while it is heating with the required proportion of hops. The stronger the wort is, the larger proportion of hops does it demand: and this is calculated in two ways, either according to the quantity of malt employed, or the richness of the wort. Where the former basis of calculation is referred to, the quantity of hops, especially in private families, where economy is not so strictly attended to as in large establishments, is one pound of hops to a bushel of malt, whether the wort is intended for the strongest ale, or the weakest small beer. In public breweries, the proportion of hops is considerably smaller, and is regulated, not merely by the quantity of malt, but the richness of the wort. For strong ales, the common proportion is about 1 lb. of hops to 1. 3 bushel of malt; for beer, the quantity is lowered to 1 lb. of hops to 1. 7 bushel of malt. When both ale and beer are brewed from the same malt, the usual practice is to put the *whole* quantity of hops in the ale-wort; and after they have been boiled a sufficient time in this, to transfer them to the beer-wort, in order to be exhausted by a second boiling.

When the hops are mixed with the wort in the copper, the liquor is brought to boil; and the best practice is to keep it boiling as fast as possible, till, upon taking a little of the liquor out, it is found to be full of minute flakes, like curdled soap. These flakes consist of the gluten and starch of the malt separated from their former solution in the wort, by the joint action, in all probability, of the heat, and the bitter extract of the hops. For the ascertainment of this important question, no regular experiments, however, have been as yet instituted.

The boiling copper is in most breweries uncovered, but in some it is fitted with a steam-tight cover, from the centre of which passes a cylindrical pipe, that terminates by several recurved branches in the upper or mashing copper: the steam, therefore, produced by the boiling, instead of being wasted, is let into the cold water of the upper copper, and thus raises it very nearly to the temperature required for mashing, besides impregnating it very sensibly with the essential oil of the hops, in which the whole of the flavour resides, and which would otherwise be discharged into the air, and thus be lost.

§ 3. *Cooling.*

When the liquor is sufficiently boiled, it is discharged into a number of shallow tubs called coolers, where it remains exposed to a free draft of air, till it has deposited the hop-seeds and coagulated flakes with which it was charged, and is become sufficiently cool to be submitted to the next process, which is that of fermentation. It is necessary that the process of cooling should be carried on as expeditiously as possible, particularly in hot weather; for unfermented wort, by exposure to a hot close air for a few hours, is very liable to contract a nauseous smell and taste, when it is said technically to be *foxed*, in consequence of small spots of white mould forming on its surface. Liquor made from pale malt, and which is intended for immediate drinking, need not be cooled lower than 75° or 80°, and in consequence may be made all the year through, except perhaps during the very hottest season; but beer from brown malt, especially if intended for long keeping, requires to be cooled to 65° or 70°, and therefore cannot possibly be made except in cool weather; hence it is that the months of March and October have always been reckoned peculiarly favourable to the manufacture of the best malt liquor.

§ 4. *Tunning and barrelling.*

From the coolers the liquor is transferred into the fermenting or working tun, which is a large cubical wooden vessel capable of being closed at pleasure. As soon as the wort is let in, it is well mixed with yeast, in the proportion of about one gallon to four barrels, and in about five hours afterwards the fermentation commences. The signs of fermentation are muddiness of the liquor, the formation of froth or yeast on the surface, and a copious disengagement of carbonic acid. In the first stage of fermentation, on taking some of the yeast in a bowl it soon falls down into a liquid; but when the fermentation is sufficiently established to allow of barrelling, the yeast has a certain degree of toughness, and will remain a long time without falling in. When the wort is let down hot into the working tun, the fermentation is conducted with the tun closed, and proceeds rapidly, so that in about 18 or 20 hours it is fit to be cleansed or put into the barrels; but when the wort is let down at 65° it requires 48 hours for the first fermentation, and is peculiarly liable to be affected by a considerable change of weather.

Although, in common practice, the coagulated fecula and gluten are deposited and left in the coolers, yet, skilful brewers mix them again with the wort by agitation, and ferment the liquor in this state. Fermentation is considerably retarded by this practice; but, in return, the liquor is much clearer and more completely fermented, as is obvious from the remarkable diminution of specific gravity which it undergoes.

The last process is transferring the liquor from the working tun to the barrels, when the fermentation is completed. During a few days, a copious discharge of yeast takes place from the bung hole, and the barrels must be carefully filled up every day with fresh liquor: this discharge gradually becomes less, and in about a week ceases; at which time the bung-hole is closed up and the liquor is fit for use, after standing from a fortnight to three months according to its strength, and the temperature at which it has been fermented.

Brewing, among *Distillers*, denotes the method of extracting the more soluble parts of vegetables with hot water, and thus procuring a solution or decoction fitted for vinous fermentation.

In which sense brewing is a necessary step towards distillation.

A fermentable solution, fit for yielding a spirit or brandy, is obtainable from any vegetable, under proper management; but the more readily and perfectly the subject dissolves, the better it is disposed for fermentation, and the production of brandies. Thus sugar, honey, treacle, manna, and other inspissated vegetable juices, which totally unite with water, into a clear and uniform solution, are more immediate, more perfect, and better adapted subjects of fermentation than roots, fruits, or herbs, in substance, the grains, or even malt itself; all which dissolve but very imperfectly in hot water.

Yet malt, for its cheapness, is generally preferred in England, and brewed for this purpose, much after the common manner of brewing for beer; only the worst malt will serve for distillation; and the tincture, without the addition of hops, and the trouble of boiling, is here directly cooled and fermented.

The grain intended for brewing is previously malted, to prepare it for dissolving more easily and copiously in the water, so as to afford a richer tincture or solution, which, after due fermentation, will yield about one half more of proof spirit than the tincture of an equal weight of unmalted corn.

Brewing is also used, in an ill sense, for the counterfeiting and compounding especially of wines. Vintners and wine-coopers are suspected of brewing wines, or mixing divers inferior sorts, to imitate some better kind. The necessity of accommodating their liquors to the palates of their guests, is another cause of brewing; insomuch that some have confessed they commonly draw out of two or three casks for every pint.

Brick

BRICK, a kind of factitious stone, composed of an argillaceous earth, tempered and formed in moulds, dried in the sun, or burnt in kilns.

The use of bricks is of the highest antiquity. The earliest buildings of Asia were of bricks, dried in the sun, and cemented with bitumen. In this manner, we learn from the historical books of the Old Testament, Nineveh was built by Nimrod; and the famous walls of Babylon, reckoned by the Greeks among the wonders of the world, were of the same materials.

Unburnt bricks were used in Egypt: the making of them was one of the oppressions to which the Israelites were subjected during their servitude in that country. The antique edifices which at present exist in Egypt are principally of stone: however, Pococke describes a pyramid of unburnt brick, called "Kloube-el-Menshieh (the bricks of Menshieh), from a village near, called Menshieh-Dashour. It was doubtless built near the plain, on account of the bricks, which seem to be made of the earth brought by the Nile, being of a black sandy earth, with some pebbles and shells in it. It is mixed up with chopped straw, in order to bind the clay together; as they now make unburnt bricks in Egypt, and many other eastern parts, which they use very much in their building. I found some of these bricks 13½ inches long, 6½ inches broad, and 4 inches thick; and others 15 inches long, 7 inches broad, and 4½ inches thick. I observed on the north side the bricks were laid lengthways from north to south, but not every where in that direction; however, I particularly took notice that they were not laid so as to bind one another. It is much crumbled and ruined, but as it is I measured it, and found it to be 157 feet on the north side, and 210 feet on the west side; it is 150 feet high. By what I could judge, from the present slope of it, I concluded that it was built with five degrees, like the pyramid of Saccara, each being about 10 feet broad and 30 deep, so that the ascent to it is easy, as the bricks are crumbled away."

The Greeks and Romans also used this material, both sun-dried and burnt. Vitruvius instances several celebrated buildings, as the walls of Athens; the cells of the temples of Jupiter and Hercules, which were of brick, the surrounding columns and entablature being of stone; the ancient walls of Arezzo in Italy; the house built by the Attalic kings at Tralles, which was always given for the habitation of those who bore the office of priests in that city. The paintings which were brought from Lacedæmon to ornament the Comitium, in the edileship of Varro and Murena, were cut from walls of brick; the house of Crœsus at Sardis; and the celebrated tomb of Mausolus, in which, though the ornaments were all of Proconnesian marble, the walls were built of brick, and (says Vitruvius) remain to this time exceedingly substantial, and the incrustation appears as polished and shining as glass.

The following directions for making unburnt bricks are given by Vitruvius. They should not be made of sandy, stony, or gravelly loam, for such kind of earth renders them heavy; and upon being wetted with rain after being laid in the wall, they swell and dissolve, and the straw which is put in them does not adhere on account of their roughness: the earth of which they are formed should be light chalky white or red. They should be made in spring or autumn, as being the best time for drying; for the intense heat of summer parches the outside before the inside is dry, which afterwards drying in the building, causes them to shrink and break. They are best when made two years before they are used, as they cannot be sufficiently dry in less time. If they are used when newly made and moist, the plaster work which is laid on them remaining firm and stiff, and they shrinking, and consequently not preserving the same height with the incrustation, it is by such contraction, loosened and

feparated. At Utica, therefore, the laws allow no bricks to be ufed before they have lain to dry five years.

Vitruvius proceeds to defcribe the different kinds of bricks, which were of three fizes; the firft, called *didoron*, were in general ufe among the Romans; they were a foot long, and half a foot broad. The other two forts were ufed by the Greeks; one called *tetradoron*, which were on every fide four palms, or one foot; the other *pentadoron*, five palms, or fifteen inches every way: the firft were ufed in private, and the latter in public edifices. They had alfo half bricks of each fort; and in building, the whole bricks were laid in one courfe, and the half in the next.

At Pitane in Afia, at Calentum in Spain, and at Marfeilles, they had bricks fo light as to fwim on water, the earth of which they were made being of the nature of pumice ftone.

When Vitruvius mentions bricks, it appears that he means fun-dried bricks; for he obferves, that bricks could not be ufed by the Romans within the city; as to fave room in fo crowded a town, the laws did not permit any walls in public places to be made thicker than one foot and a half, while brick walls of that thicknefs would not fupport more than one ftory. Accordingly, the walls were built with hewn ftone, *teftaceous fubftances* (ftructuris teftaceis), or rubble. That thefe teftaceous fubftances were tiles, is evident, for he obferves, that it could not be known at firft whether they were of good loam and well burnt, but that they fhould be laid in a roof during a winter and fummer before they were ufed in a wall.

Auguftus boafted that he had found Rome of brick, and left it of marble. It could be only fun-dried bricks that he referred to, for baked bricks were ufed in the moft fumptuous edifices: the temple of Peace, the Pantheon, and all the Thermæ were of this material.

Whatever may be the precife time of the introduction of baked bricks in the edifices of Rome, they appear to have been always fquare. M. Quatremere de Quincy, in the Encyclopedie Methodique, obferves, that in his refearches among the antique buildings of Rome, he has found bricks of three fizes. The leaft were $7\frac{1}{2}$ inches fquare, and $1\frac{1}{2}$ thick; the medium ones $16\frac{1}{2}$ inches fquare, and from 18 to 20 lines in thicknefs; and the larger ones 22 inches fquare, by 21 or or 22 lines thick. The fmaller bricks were employed to face walls of rubble work; and to make a better bond with the wall, they were cut diagonally into two triangles, the longer fide was placed on the outfide, and the point towards the interior of the work. To tie more effectually the facing with the rubble, they placed at every four feet in height one or two courfes of the large fquare bricks. The large bricks were alfo ufed in the arches of openings or difcharge, which were neceffary in the building.

No long bricks, fuch as are ufed at prefent, are found in antique conftructions.

In modern times, bricks have been ufed in all countries. Chardin thus defcribes the manufacture of bricks in Perfia. The material of Perfian buildings is brick, either dried in the fun or burnt in the fire. The tiles or bricks of earth are made in thin wooden moulds, of 8 inches long, 6 wide, and $2\frac{1}{2}$ inches thick. The labourers temper with their feet the earth, which is generally mixed with ftraw cut very fmall, to give it more confiftence, and that the bricks may laft longer and not break. They pafs the hands over the bricks to fmooth them, after having dipped them in a veffel of water mixed with ftraw, ftill finer than was at firft ufed. Then taking off the mould they leave the bricks to dry for two or three hours, after which they are ranged over one another, where they remain till the drying is completed.

The baked bricks are made of two parts of earth and one of cinders, well tempered together, in moulds larger than for the others. They leave them to dry in the fun for feveral days, then place them in a large furnace, ranged one over the other, at fome diftance, which they fill with plafter. They clofe the furnace and light the fire, which is kept up for three days and nights.

Bricks have feveral advantages over ftone as building materials. From their porous ftructure they unite better with the cement ufed: they are lighter than ftone, and not fubject to attract damps and moifture.

The earth proper for the manufacture of bricks is a clayey loam, neither abounding too much in fand, which renders the ware heavy and brittle, nor yet with too large a proportion of argillaceous matter, which caufes it to fhrink and crack in drying.

The general procefs of the manufacture is as follows: The earth fhould be dug in the autumn; it fhould lie during the whole of the winter expofed to the froft, as the action of the air, in penetrating and dividing the particles of the earth, facilitates the fubfequent operations of mixing and tempering. During this time the earth fhould be repeatedly turned and worked with the fpade. In the fpring the clay is broken in pieces, and thrown into fhallow pits, where it is watered and fuffered to remain foaking for feveral days. The next ftep is that of tempering the clay, which is generally performed by the treading of men or oxen. In the neighbourhood of London, however, this operation is performed by means of a horfe-mill. The tempering of the clay is the moft laborious part of the procefs, and that on which the perfection of the manufacture effentially depends. It is to neglect in this part, that we are chiefly to attribute the bad quality of modern bricks, in comparifon with the ancient. All the ftones fhould be removed, and the clay brought to a perfectly homogeneous pafte, ufing the leaft poffible quantity of water.

The following experiment, made by M. Gallon, merits attention. He took a certain quantity of the earth, prepared for the making of bricks; he let it remain for feven hours, then caufed it to be moiftened and beaten during the fpace of thirty minutes: the next morning the fame operation was repeated, and the earth was beaten for thirty minutes; in the afternoon it was again beaten for fifteen minutes. Thus this earth had only been worked for an hour and a quarter longer than ufual, but at three different times. The material had acquired a greater denfity by this preparation; for a brick made with this earth weighed five pounds eleven ounces, while another brick, made in the fame mould, of the earth that had not received this preparation, weighed only five pounds feven ounces. Then having dried thefe bricks in the air, during the fpace of thirteen days, and having burnt them along with others, without any particular precautions, they were examined when taken from the kiln, and it was found that the bricks made of the earth which had been the moft worked ftill weighed four ounces more than the others, each having loft five ounces by the evaporation of the moifture. But their ftrength was very different; for on placing them with the centre on a fharp edge, and loading the two ends, the bricks formed with the well-tempered earth, were broken with a weight at each end of 65 pounds or 130 pounds in all, while the others were broken with 35 pounds at each end, or 70 pounds in the whole.

The earth, being fufficiently prepared in the pits, is brought to the bench of the moulder, who works the clay into the brick-moulds, and ftrikes off the fuperfluous earth. The bricks are delivered from the mould and ranged on the ground; and when they have acquired a fufficient hardnefs

to admit of handling, they are dreſſed with a knife, and ſtaked or built up in long dwarf walls, and thatched over, where they remain to dry.

The burning of bricks, which is the next operation, is performed either in a kiln or a clamp. In the former, the bricks being ſet in, and the kiln covered with pieces of brick, they put in wood to dry them with a gentle fire; and this they continue till they are pretty dry, which is known by the ſmoke turning from a whitiſh to a ſhin black ſmoke. They then ceaſe to put in wood, and proceed to burn with bruſh, furze, ſtraw, brake, or fern faggots, having firſt cloſed up the mouth of the kiln with a thin log (pieces of brick piled upon one another and cloſed with wet brick earth inſtead of mortar), then they continue to put in more faggots till the kiln and its arches look white, and the fire appears at the top, upon which they ſlacken the fire for an hour, and let all cool by degrees. Thus they continue alternately heating and ſlacking, till the ware be thoroughly burnt, which is uſually effected in 48 hours.

About London they burn in clamps, built of the bricks themſelves, after the manner of arches in kilns, with a vacancy betweeen each brick's breadth, for the fire to play through; but with this difference, that, inſtead of arching, they gather the flues over by making the bricks project over one another. The place for the fuel is carried up ſtraight on both ſides till about three feet high; they then nearly fill it with wood, and over that lay a ſtratum of ſea coal, and then overſpan the arch; ſea-coal is alſo ſtrewed between every row of bricks in the clamp; laſtly, they kindle the wood which communicates with the coals; and when all is burnt out, they conclude that the bricks are ſufficiently burnt.

The proper burning of bricks is a matter of conſiderable difficulty, and requires an experienced workman; as it is neceſſary to maintain an equal heat throughout the whole maſs, neither too little, which would leave the bricks weak and crumbly, nor too great, which would cauſe them to run together into a vitrified ſlag. This operation is much better performed in kilns than in clamps, as the fire can be kept up and regulated at diſcretion; while in clamps, as the whole of the fuel muſt be put in at once, the manufacturer is always tempted to uſe too little, and the outſide bricks are neceſſarily under-burnt. Theſe are called ſamel bricks, and are ſold at an inferior price.

The legiſlature has often interfered to regulate the manufacture of bricks. By ſtat. 12 Geo. I. cap. 35, earth or clay, deſigned for making bricks for ſale, ſhall be dug and turned at leaſt once between the 1ſt of November and the 1ſt of February, and not be made into bricks till after the 1ſt of March, and no bricks be made for ſale but between the 1ſt of March and 29th of September. But by ſtat. 10 Geo. III. cap. 49. earth may be dug for making bricks at any time in the year, provided ſuch earth be turned once before it be made into bricks. And by the former ſtatute, no Spaniſh is to be mixed with the earth or breeze uſed in the burning of bricks: and all bricks are to be burnt either in kilns, or diſtinct clamps, each ſort by itſelf.

By ſtat. 3 Geo. II. cap. 22. there may be mixed with the brick-earth any quantity of ſea-coal aſhes, ſifted or ſcreened through a ſieve or ſcreen half an inch wide, and not exceeding 20 loads, to the making of 100,000 bricks, each load not exceeding 36 buſhels. And breeze may be mixed with coal in the burning of bricks in clamps for ſale, &c. Stock-bricks and place-bricks may be burnt in one and the ſame clamp, ſo that the ſtock bricks be ſet in one diſtinct parcel, and not mixed and ſurrounded with place-bricks.

For the more effectually ſecuring the obſervation of theſe laws, it was enacted, by 12 Geo. I. cap. 35. for the better diſcovery of offenders, that the maſter and wardens of the company of tylers and bricklayers ſhould have power to ſearch brick-kilns, &c.; but they having permitted, and even encouraged divers perſons to make bricks contrary to the directions in the ſaid act, by 2 Geo. II. cap. 15. they are diveſted of that power, and any two, three, or more perſons, appointed by the juſtices of peace, are empowered, within 15 miles of London, to go in the day-time into any grounds, ſheds, or places where any clay or earth ſhall be digged or digging for bricks or pan-tiles, or any bricks or pan-tiles ſhall be making or made for ſale, and there to view, ſearch, and inſpect the ſame, &c. Offenders to forfeit 20 ſhillings for every thouſand of unſtatutable bricks, and 10 ſhillings for every thouſand of ſuch tiles; one moiety to the uſe of the proſecutor, the other to the poor of the pariſh where the offence ſhall be committed.

By 17 Geo. III. cap. 42. all bricks made for ſale ſhall, when burned, be not leſs than 8¼ inches long, 2½ thick, and 4 wide.

By 43 Geo. III. c. 69. (conſolidating the exciſe duties) paſſed July 4, 1803, every thouſand of bricks made in Great Britain, not exceeding 10 inches long, 3 inches thick, and 5 inches wide, is liable to a duty of 5s. and exceeding the fore-mentioned dimenſions to 10s.; and every thouſand of bricks made in Great Britain, and ſmoothed or poliſhed on one or more ſides, not exceeding the ſuperficial dimenſions of 10 inches long by 5 inches wide, is ſubject to a duty of 12s. and if ſuch bricks exceed theſe dimenſions, to the duty on paving tiles. The ſaid duties are to be paid by the makers. An additional duty of 10d. per thouſand was impoſed on bricks and tiles in the ways and means for the year 1805.

The different kinds of bricks made in this country are place bricks, grey and red ſtocks, marle facing bricks, and cutting bricks. The place-bricks and ſtocks are uſed in common walling. The marles are made in the neighbourhood of London, and uſed in the outſide of building; theſe are very beautiful bricks, of a fine yellow colour, hard, and well burnt, and in every reſpect ſuperior to the ſtocks. The fineſt kind of marle and red bricks are called cutting bricks, they are uſed in the arches over windows and doors, being rubbed to a centre and gauged to a height. There is alſo a fine kind of white bricks made near Ipſwich, which are uſed for facing, and ſometimes brought to London for that purpoſe. The Windſor bricks, or fire-bricks, which are made at Hedgerley, a village near Windſor, are red bricks, containing a very large proportion of ſand; theſe are uſed for coating furnaces, and lining the ovens of glaſs-houſes, where they ſtand the utmoſt fury of the fire. Dutch clinkers are alſo imported, long narrow bricks, of a brimſtone colour, very hard and well burnt; they are frequently warped, and appear almoſt vitrified by the heat. The uſe of them is for paving yards and ſtables.

Brick-*walls*. See Wall.

Bricks, *Oil of*. See Oil *of Olives*.

Brick-*duſt*. It is a cuſtom with ſome perſons to reduce this ſubſtance to a very fine powder, and give it, inſtead of chalk, in the heart-burn. Many of the lozenges, ſo much famed for the cure of this diſorder, and ſold under the pompous name of coral lozenges, are only made of a mixture of this uncouth medicine, and ſugar, made into the conſiſtence of paſte, with gum tragacanth reduced to a mucilage with roſe-water.

Brick is alſo uſed in ſpeaking of divers other matters made in the form of bricks.

In which ſenſe, we ſay a penny-brick, or brick-bread. Some alſo mention brick-tin, a ſort of tin in that ſhape

brought from Germany; and brick-soap, made in oblong pieces, from a pound and a half to three pounds.

Brick, πλινθιον or πλινθια, *laterculus*, in the *Military Art*, denotes one of the forms of the Grecian army, which was drawn up in the figure of a brick or tyle, with four unequal sides; its length being extended towards the enemy, and exceeding its depth. That of the brick inverted, denominated πυργος, *turris*, was an oblong square, after the fashion of a tower, with the small end towards the enemy. Homer. Iliad. μ. v. 43.

Bricks, or Briques, in *Heraldry*, are figures or bearings in arms, resembling a building of bricks; being of a square form, like billets; from which they only differ in this, that they shew their thickness, which the other do not.

Brick *earth*, in *Agriculture*. See *Brickish* Soil.

Brick *kiln*, a place to burn bricks in.

Brick-*layer*, an artificer whose business it is to build with brick, or make brick work.

Brick-layers work or business, in London, includes tyling, walling, chimney work, and paving with bricks and tyles. In the country, it also includes the mason's and plaisterer's business. The materials used by brick-layers, are bricks, tyles, mortar, laths, nails, and tyle-pins. Their tools are, a brick-trowel, wherewith to take up mortar; a brick ax, to cut bricks to the determined shape; a saw, for sawing bricks; a rub-stone, on which to rub them; also a square, wherewith to lay the bed or bottom, and face or surface of the brick, to see whether they be at right angles; a bevel, by which to cut the under sides of bricks to the angles required; a small trannel of iron, wherewith to mark the bricks; a float stone, with which to rub a moulding of brick to the pattern described; a banker to cut the bricks on; linepins, to lay their rows or courses by; plumb-rule, whereby to carry their work upright; level to conduct it horizontal; square, to set off right angles; ten-foot rod, wherewith to take dimensions; jointer, wherewith to run the long joints; rammer, wherewith to beat the foundation; crow and pick-ax, wherewith to dig through walls.

The London brick-layers and tylers make a regular company, which was incorporated in 1568, and consists of a master, two wardens, twenty-eight assistants, and one-hundred and eight on the livery.

A brick-layer and his labourer will lay in a day about 1000 bricks, in whole work, on a solid plane, when the wall is but a brick and a half, or two bricks thick; and since a cubic yard contains 460 bricks, he will lay above two cubic yards in a day: and hence it may be easily computed how many brick-layers are required to finish a certain piece of work in a given time.

Brick-laying is one of the arts subservient to architecture. Moxon has an exercise express on the art of brick-laying, wherein he describes the materials, tools, and methods of working used by brick-layers. See *Brick* Walls.

Brick-*work*. There is very little to be added under this head, to what has been said in the preceding article, to which the reader is referred.

Bricks, when used in external walls, are generally worked in what is called Flemish bond, that is, with headers and stretchers alternately, and the courses so disposed, that the middle of the bricks of one fall over the joints of the next. Brick-work is measured by the square foot reduced to the thickness of one brick and a half; thus a wall two bricks thick, ten feet long, and three feet high = 30 square feet would be called 40 feet reduced. It is valued by the rod of 272 feet. Facing and gauged arches are measured by the superficial square foot, and cornices by the foot running or the length.

Bridge

BRIDGE, in *Architecture*, from the Saxon bpic, is a ſtructure of carpentry, maſonry, or iron-work, built over a river, canal, or valley, for the convenience of paſſing from one ſide to the other, and may be conſidered as a road ſupported in the air by arches or lintels, and theſe again ſupported by proper piers or butments.

Bridges generally form the continuation either of an highway or of a ſtreet; in the firſt caſe they are frequently built in a rude and cheap manner, and too often without proper attention to thoſe principles which would enſure permanence and ſolidity to the ſtructure; but when they take their lead or direction from a principal ſtreet in a capital city, their conſtruction is attended with great expence, and a degree of elegance and durability is required in their formation, which calls for the utmoſt judgment and ſkill in the architect. The magnitude of bridges alſo varies with their ſituation. When they are erected in places not much frequented, they are often, without any impropriety, made about eight or ten yards wide, but the breadth of a bridge for a great city ſhould at leaſt be ſuch as to allow a ſafe and eaſy paſſage for three carriages, and two horſemen abreaſt, and for three or four foot paſſengers in the ſame manner on each banquet.

A ſtately bridge over a large and rapid river, while it is one of the moſt difficult, is juſtly eſteemed one of the moſt noble and ſtriking ſpecimens of human art. To behold grand arches compoſed of an immenſe quantity of ſmall materials, ſo diſpoſed and united together as to form one compacted body, which, beſtriding the ſtream, affords above an ample communication with the diſtant ſhores, and allows below an uninterrupted paſſage to navigation, is enough to awaken the admiration of every ſpectator. The art of bridge-building, accordingly, has received conſiderable attention from writers on architecture, the earlieſt of whom is Alberti, who has

has given several judicious precepts, which, with little alteration, were afterwards laid down by Palladio, Serlio, and Scamozzi. The best of these rules are also given by Goldman and Baukhurst, and by Hawkesmoor in his history of London bridge. M. Gautier has a considerable volume upon bridges ancient and modern. M. Belidor has treated on this subject, in his "Archit. Hydraulique;" and M. Parent, in his "Essais and Recherches Mathemat." vol. iii. De la Hire, too, has touched upon the subject, in his "Traité de Mechanique;" Perronet also has given the result of his experience in a magnificent work, which has acquired great credit in France; Bossut has given an excellent treatise in the "Memoires de l'Academie;" and Regemortes, in the year 1771, published an account of a bridge constructed by him on the river d'Allier at Moulins. This bridge consists of thirteen arches, 64 feet span each, and 24 feet high.; semi-ellipsis.—The top of the bridge is level. Mr. Rion published, in 1760, "Short Principles for the Architecture of Stone Bridges;" and Mr. Semple has given some excellent practical remarks in his "Treatise on Building in Water," published in 1776. Other writers on the subject of arches and bridges are Muller, Labelye, Atwood, Emerson, and Dr. Hutton in his "Principles of Bridges."

History of Bridges.—We have no records which will enable us to trace the art of bridge-building from its first rude and imperfect state, through its various stages of improvement, to its present maturity and grandeur. It cannot, however, be doubted, that men in the earliest ages would do as our villagers do at present: the accidents of nature would present a model; a fallen tree, or a wave-worn cavern would frequently form a natural bridge, and the first bridges were composed of lintels of stone or wood, either of length sufficient to stretch from bank to bank, or when this was impracticable, supported by piers or posts placed in the bed of the river. There are still considerable structures of this kind in China, and many of them in this country on a rural scale. This method, however, would in many situations be opposed by insuperable difficulties: the frequent piers required for the support of lintels would, by contracting the water-way, increase a strong current to a dangerous, rapid torrent, impeding navigation, and undermining and destroying the piers themselves. It would, therefore, be found necessary, in constructing bridges over rapid rivers, to have the supports as few and distant, and the openings as wide as possible; this could only be effected by the use of arches of stone and trusses of wood; accordingly these inventions must have been completed before bridges of importance had become common.

The origin of arches is so obscure, and our lights so few, that it is, perhaps, impossible at this time to determine to whom this invention is due. The Egyptians, skilful as they were in architecture, do not appear to have possessed arches; their temples were roofed with slabs laid horizontally from column to column, and the openings covered with massy lintels, or, as in the passages within the great pyramid, with courses of stones projecting over one another like inverted steps, till they met at top. Some of their tombs, however, which are excavated in the solid rock, have the appearance of vaults, as the ceilings are hollowed out in a circular form, and there are instances of hemispherical niches. Similar forms also prevail in the Hindoo excavations at Ellore, in the Deccan, and in the island of Salsette. See Mr. Daniel's Plates of Indian Antiquities and Hindoo Excavations. This practice, though it has the form, has not the principle of an arch; for it is evident that a solid lintel gains no strength by being hollowed in the middle, neither is the execution more difficult; and though both the Hindoos and Egyptians attained this step, they never, at least, there are no remains which authorize us to suppose that they ever did make any further progress in the discovery of arches.

The Chinese are acquainted with the use of arches, and from the known adherence of this nation to ancient modes, we may attribute a very high antiquity to this practice among them. Their arches are of various forms, pointed, semicircular, semi-elliptical, and horse-shoe shaped; their construction, as described by Mr. Barrow, is curious, "each stone, from five to ten feet in length, is cut so as to form a segment of the arch, and, as in such cases there is no key-stone, ribs of wood fitted to the convexity of the arch are bolted through the stones by iron bars, fixed fast into the solid parts of the bridge. Sometimes, however, they are without wood, and the curved stones are morticed into long transverse blocks of stone." Mr. Barrow proceeds to observe, that "there are, however, arches wherein the stones are smaller, and pointed to a centre as in ours. I have understood from the late captain Parish, that no masonry could be superior to that in the great wall, and that all the arched and vaulted work in the old towers was exceedingly well turned."

However, the most ancient arches, of whose erection we have dates, are those in the cloacæ of Rome, which were begun by Tarquinius Priscus. There are also arches in several Greek theatres, stadia, and gymnasia, among others, the theatre of Bacchus at Athens, erected, probably, 400 years before the Christian era.

The Greeks, it is well known, often neglected the most necessary objects to lavish enormous sums on works of magnificence, though destitute of any essential utility. Pericles, so far from thinking of aquæducts, could never be prevailed upon even to construct a bridge over the little Cephisus. The Romans discovered, in this respect, a more solid manner of thinking; they were, it is true, much attached to pomp, but they never neglected works of public utility: they never risked their lives unnecessarily in crossing a torrent, as the Athenians must have done previous to the arrival of the emperor Adrian; for it was Adrian who undertook to form, by a bridge, a safe communication across the Cephisus, between the territories of Attica and Eleusis, on the most frequented road of Greece. While, therefore, we ascribe to the Greeks the use of arches and vaults, properly constructed for covering various openings in their buildings, we must look to the Romans for the application of arches to bridges, and for the chief improvements in those useful structures.

The construction of the Roman bridges is best described by Bergier: they possessed all the requisites which are met with in a modern bridge; they consisted of *pilæ*, or piers, *fornices*, or arches, *sublices*, or butments, *pavimenta*, and *aggeres*; the roads over in the middle for carriages, on each side of which were *decursoria*, or banquets, somewhat higher than the rest of the road for foot passengers, and separated from it by a *sponde*, or railing, and sometimes even covered over to shelter passengers from the rain, as in the Pons Ælius. Among the Romans, the building and repairing of bridges was first committed to the priests, thence named *pontifices*, then to the censors and curators of the roads, and lastly, the emperors took the care of the bridges into their own hands.

The ancient bridges of Rome were eight in number. The bridge of *Fabricius*, which joins the island of the Tyber to the city; it is now called *Ponte Quatro Capi*, from the four heads of Janus, which are placed upon it. The bridge of *Cestius*, now called of *San Bartholomeo*, which from the other side of the island passes to Trans-Tevere. The first bridge built at Rome, which was of wood, and thence called *Pons Sublicius*, was afterwards rebuilt of stone by Æmilius

Lepidus; ſome veſtiges are ſtill to be ſeen at the bottom of the Aventine mountain. The bridge called *Senatorius*, and alſo *Palatinus*, of which ſome arches remain near to Santa Maria. The bridge of *Janiculus*, which, as it was rebuilt by Sixtus IV. is now called *Ponte Siſto*. The *Milvius*, now called *Ponte Molle*. There are alſo, near the hoſpital of Santo Spirito, the remains of the Triumphal Bridge, ſo named becauſe the proceſſion of the triumphs paſſed over it to go to the Capitol. Near to this is the bridge of Santo Angelo, formerly called *Pons Ælius*, from the Emperor Ælius Adrianus; it was repaired by Nicholas V. and afterwards ornamented with ſtatues by Clement IX. Of theſe bridges the laſt mentioned is the only one at all remarkable for ſize.

One of the moſt celebrated of the bridges of antiquity was that built by Trajan over the Danube. It was erected by that emperor for the conveniency of ſending ſuccours to the Roman legions on the other ſide of the Danube, in caſe they ſhould be ſuddenly attacked by the Daci, but demoliſhed by his ſucceſſor, Adrian, leſt the barbarians, overpowering the guards ſet to defend the bridge, ſhould, by means of it, pour into Mæſia and cut off the garriſons there. Some of the piers are ſtill to be ſeen in the middle of the river, near the town of Warhel in Hungary. According to the deſcription given by Dion Caſſius, (lib. 68. cap. 13.) this bridge conſiſted of 20 piers of ſquared ſtone, each of them 150 feet high above the foundation, 60 feet in breadth, and 170 feet diſtant from each other, which was the ſpan or width of the arches, ſo that the whole length of the bridge was nearly 1500 yards. Conſiderable doubt, however, is thrown on this account by Montfauçon, who obſerves, that in the baſſo relievos of the Trajan column, this bridge is repreſented with only four piers beſides the abutments, which ſupport three larger arches or truſſes of wood, with two ſmaller ſtone arches at the extremities.

On the road from Loretto to Rome, at the bottom of the hill on which the town of Narni is ſituated, there are the broken remains of an ancient bridge, which appears to have been very magnificent. Its form and dimenſions are ſtated by Agoſtino Martinelli, in a book printed at Rome in 1676, entitled "Deſcrittione de diverſi Ponti eſiſtenti ſopra la Fiume Nera & Tevere." This bridge which joined two mountains, between which flows the river Nera, was of an extraordinary height, and was built in this manner by Auguſtus, that the inhabitants of Narni might paſs on a level from one mountain to another. The whole length was 850 palms (637 feet). It conſiſted of four large and unequal arches; the firſt, which was entire in the time of Martinelli, while all the others were broken, was 100 palms (75 feet) in ſpan, and 150 palms (102 feet) in height; the ſecond arch 180 palms (135 feet) in ſpan; the third 152 palms (114 feet); and the fourth, which abutted againſt the other mountain, 190 palms, or 142 feet.

The *Pont du Garde*, about 3 leagues from Niſmes, is a very conſiderable Roman work. This ſtructure was at once a bridge over the river Gardon, and an aquæduct which carried water to Niſmes. The firſt row of ſix arches, which is the bridge, ſupports a ſecond arcade of eleven arches, which is continued upon the ſlope of the two mountains forming the valley; above the ſecond is a third arcade of 35 arches, much ſmaller than thoſe below, ſupporting the canal on a level with the two mountains, along which the water was conducted to Niſmes by a continued aquæduct. This remarkable edifice is built of ſtones of an extraordinary ſize, connected together without cement by iron cramps. The length of the firſt arcade is about 465 feet, of the ſecond 780, of the third 850, and the height from the river 190 feet.

The celebrated Roman bridge *Pont, St. Eſprit*, near Lyons, has long been reckoned one of the fineſt and boldeſt of the ancient bridges in France. Its whole length is upwards of 800 yards; it is very crooked, bending in many places, and making ſeveral unequal angles, eſpecially in thoſe parts where the Rhone has the ſtrongeſt current. The arches are from 15 to 20 fathoms wide, and have their feet, or the bottoms of the piers, protected by two pedeſtals which project from them; the lower part of the piers conſiſts of ſeveral courſes of footings jutting out like ſteps. Between the great arches there are ſmaller arches like windows that come down nearly to the top of the pedeſtals, about the middle of the pier. This mode of conſtruction was adopted with a view of breaking gradually the mighty force of the Rhone, the ſeveral courſes of ſteps jutting out from the piers were intended to oppoſe and break the ſtream by portions, and prevent it from coming with its whole force at once upon the fabric; and when the flood ſhould riſe ſo high as to cover the ſteps and pedeſtals, then the ſmall window-like arches would aſſiſt to convey the water through, which might otherwiſe endanger the great arches.

The bridge of Brioude is of great antiquity, and very remarkable, as the largeſt ſtone arch with which we are acquainted. This bridge has only one arch, under which paſſes the whole ſtream of the river Allier. The arch is formed of two ranks of ſquared ſtones; all the reſt of the fabric is of rubble work. The two extremities of the arch are founded upon the rock, which occaſions the ſpringing on one ſide to be higher than on the other; its ſpan is 181 feet, and its greateſt height from the water to the ſoffit of the arch is 68 feet 8 inches, and the width of the bridge between the parapets is 13 feet.

In the middle ages bridge-building was reckoned among the acts of religion; and a regular order of hoſpitallers was founded by St. Benezet, towards the cloſe of the 12th century, under the denomination of pontifices or bridge-builders, whoſe office was to aſſiſt travellers by making bridges, ſettling ferries, and receiving ſtrangers in hoſpitals or houſes built on the banks of rivers. We read of a hoſpital of this kind at Avignon, where the hoſpitallers dwelt under the direction of their firſt ſuperior St. Benezet. The Jeſuit Raynaldus has a treatiſe expreſsly on St. John the bridge-builder.

The bridge of Avignon was begun in the year 1176, and finiſhed in 1188; it conſiſted of 18 arches, and was about 1000 yards in length. Several of its arches have been deſtroyed by the rapidity of the currrent together with the force of the ice.

Over the ſeveral canals at Venice are laid nearly 500 bridges of different ſizes; the greater number of them are of ſtone. The chief of theſe, called the *Rialto*, is celebrated as a maſter-piece of art: it conſiſts of one flat and bold arch, nearly 100 feet ſpan, and only 23 feet high above the water, and was built in 1588 to 1591, after a deſign of Michael Angelo. The breadth of the bridge, which is 43 feet, is divided by two rows of ſhops into three narrow ſtreets, that in the middle being the wideſt; and there is in the centre an open archway, by which the three ſtreets communicate with one another. At each end of the Rialto is an aſcent of 56 ſteps; the view from its ſummit is very lively and magnificent. The whole exterior of the ſhops and the bridge is of marble. The foundation extends 90 feet, and reſts upon 12,000 elm piles. This ſtructure coſt the republic 250,000 ducats.

The aquæduct bridge of Alcantara, near the city of Liſbon, is one of the moſt magnificent works of the kind ever executed. It was begun in the reign of John V. king of

Portugal, in the year 1713, and finished the 6th of August 1732. The architect, under whose inspection it was begun and finished, was the brigadier Mansel de Maya. The streams which pass through this duct, for the use of the inhabitants of the city of Lisbon and villages adjacent, have their chief supply from a spring near the Riberia de Caranque, about three leagues and a half from Lisbon, where the aqueduct commences; and the water is conveyed from thence through the hills by subterraneous passages, where some other springs unite with it, and across many valleys on the tops of ranges of very magnificent arches, of which that crossing the vale of Alcantara is the chief. From a subterraneous course the water is conveyed through the building on the top of the arches by means of two channels, each of which is about 12 inches deep; it generally flows about the depth of 7 inches, and is an abundant and never-failing supply of water to Lisbon. The interior height of the building is about 13 feet; and through the centre, between the streams, is a wide handsome walk or foot-path, paved with beautiful free-stone. The building is continued the same height and width through the whole of the aqueduct from Lisbon to the spring, near the Riberia de Caranque, so that if by accident any part becomes out of repair, the workmen have easy access to it. The subterraneous passages are lighted and ventilated by frequent openings made from the surface of the earth into the aqueduct; and over each of these openings turrets or square towers are erected, which have windows latticed with iron bars to admit the light and air, and at the same time to prevent mischievous persons from throwing any thing into the building to injure it.

This pile is lighted and ventilated by 79 windows and 16 turrets; the former are three feet seven inches long by 13 inches wide, railed with iron and latticed with bars; the latter rise 23 feet six inches above the roof, and are 16 feet square; beneath every second turret is an arched door-way into the aqueduct on each side of the building, wherein the water flows, and between that building and a parapet wall is a foot-path leading from Lisbon towards the very pleasant village of Bemsique, about 4 miles from Lisbon, where several gentlemen have their quintas or country-seats: one in particular, the quinta of Gerard de Visme esq. an English merchant of the first eminence, must not pass unnoticed; it is a perfect palais enchanté, whose shady bowers, beautiful gardens, fine ponds, purling streams, and sportive fountains, are frequently honoured with visits by the queen and royal family.

The water channel under the grand arch is about 24 feet wide, and seven feet deep, but, except in very rainy seasons, no water passes through this channel; the small running stream constantly passing through the vale of Alcantara is conveyed by a very narrow channel under the pavement through the grand arch, and then continues its course through the valley, in a stream between two and three feet wide till it empties itself into the Tagus at Alcantara bridge, about the distance of two miles from the aqueduct. The expence attending the execution of so magnificent a work, and keeping the same in repair, has been immense, yet the small tax of a single rey on every pound of meat, raises a fund sufficient for the purpose. There is a chapel seen through the eleventh arch, dedicated to Nossa Senhora dos Terramotos, our Lady of the Earthquakes; in commemoration of that dreadful event the earthquake in 1755, when the greatest part of the city of Lisbon, with most of her stately buildings, and magnificent temples, were levelled with the ground.

The width of the different Arches are as under:

Number.	WIDTH. Feet.	Inches.	Number.	WIDTH. Feet.	Inches.
1	22	0	19	44	4
2	29	0	20	36	5
3	43	0	21	36	5
4	43	0	22	36	5
5	56	0	23	35	5
6	60	0	24	29	2
7	70	0	25	29	2
8 Grand A.	108	5	26	29	2
9	72	0	27	29	2
10	65	10	28	29	2
11	65	10	29	29	2
12	65	10	30	21	10
13	54	8	31	21	10
14	54	8	32	21	10
15	54	7	33	21	10
16	44	4	34	21	10
17	44	4	35	21	10
18	44	4			

The height of the grand arch is 227 feet, and the total length of the piers and arches 2464 feet.

Several of the bridges in France are remarkable for their size and boldness of construction, among which may be mentioned the bridge of Neuilly, built by M. Perronet, over the Seine, on the alignment of the great avenue of the Champs Elysées, in front of the palace of the Tuilleries. This bridge, which is level at top, consists of five equal arches of 120 feet French (128 feet English) in span, and 30 feet French (32 feet English) rise. The arches are oval, composed of eleven arcs of circles of different diameters; thus the upper portion of the arch was formed with a circle of 160 feet radius, which, by its settlement during the building, and after the striking of the centres, was flattened, till it became an arc of a circle of 259 feet radius, differing so little from a platband, that, as Perronet observes, the rise of the curve, in a length of 33 feet, amounted only to 6 inches 9 lines. The piers are 14 feet wide, and the breadth of the bridge 48 feet. It was begun in the year 1768, and terminated in 1780.

The bridge on the Seine, at Mantes, consists of three arches, that in the centre having an opening of 120 feet French (128 English), and the two others 108 feet French (116 English); the piers being 25 feet 6 inches wide, and the abutments 29 feet. This structure was begun by M. Hupeau in 1757, and completed by Perronet.

The bridge of Pont-Sainte-Maixence, on the river Oise, on the great road from Paris into Flanders, is also a work of Perronet's. This bridge, which is 41 feet wide, has three arches of 77 feet opening each, being a segment of a circle described with a radius of 118 feet. Each pier is singularly composed of four cylindrical pillars 9 feet diameter, leaving, therefore, three spaces or intercolumniations between them, which are arched over, the two external ones closed with a thin walling, and the middle one left open.

The bridge over the Loire, at Orleans, is composed of nine arches, which spring at 12 inches above low water; the middle arch is 106 feet in span, with a rise of 30 feet; the two arches at the extremities being 98 feet wide and 26 feet high, and the others in proportion; the four middle piers 19 feet, the four others 18 feet, and the abutments 23 feet 6 inches thick, making the whole length 1100 feet; the arches are oval, described from three centres. This bridge was built by M. Hupeau, begun in 1750, and finished in 1760.

We have many bridges of confiderable note in our own country. The triangular bridge at Croyland in Lincolnfhire, which was erected about the year 860, is faid to be the moft ancient Gothic ftructure remaining entire in the kingdom. There are two circumftances in the conftruction of this bridge, which render it an object of great curiofity. Firft, it is formed by three femi-arches, whofe bafes ftand in the circumference of a circle, at equal diftances from each other. Thefe unite at the top; and the triune nature of the ftructure has led fome to imagine that it was intended as an emblem of the Trinity. Secondly, the afcent on each of the femi-arches is by fteps paved with fmall ftones fet edge-ways, and is fo fteep, that none but foot-paffengers can go over the bridge: horfemen and carriages frequently pafs under it, as the river in that place is but fhallow. For what purpofe this bridge was really defigned, it is difficult, if not impoffible, to determine. Utility, it is obvious, was one of the leaft motives to its erection. To boldnefs of defign and fingularity of conftruction it has more powerful claims; and thefe qualities it muft be allowed to poffefs in as great a degree as any bridge in Europe. Although this bridge has been erected fo many centuries, it exhibits no marks of decay: twelve months ago there were no fiffures to be perceived in either of the arches, and all that was miffed were a mound and fceptre, which have been torn from the hands of a ftatue of king Ethelbert by the ruthlefs hand of time.

London bridge is in the old Gothic ftyle, and had twenty fmall locks or arches; but there are now only 19 open, two having lately been thrown into one in the centre. It is 940 feet long, 44 high, and 47 clear width between the parapets. The piers are from 15 to 35 feet thick, with fterlings projecting at each fide and end, fo that the greateft water-way, when the tide is above the fterlings, is 545 feet, fcarcely half the breadth of the river; and below the fterlings the water-way is reduced to 204 feet, caufing a dangerous fall at low water. London bridge was firft built with timber in the reign of Ethelred, between the years 993 and 1016; it was repaired, or rather rebuilt of timber in 1163, and the prefent ftone bridge was begun under king Henry II. in 1176, and finifhed under king John in the year 1209. It is probable there were no houfes on the bridge for upwards of 200 years, fince we read of a tilt and tournament held on it in 1395. Houfes were erected upon it afterwards, but being found a great inconvenience and nuifance, they were removed in 1758, and the avenues to the bridge enlarged, and the whole made more commodious: the two middle arches were then thrown into one, by removing the pier from between them. The expence of the repairs amounted to above 80,000l.

There were other bridges in England built in the manner of London bridge; as the bridge at Rochefter, which is 550 feet long, and has 11 arches; alfo the late bridge at Newcaftle upon Tyne, which was broken down by a great flood in the year 1771, for want of a fufficient fpace for water-way through the arches. The longeft bridge in England is that over the Trent at Burton, built by Bernard abbot of Burton, in the 12th century. It is all of fquared free-ftone, and is ftrong and lofty, 1545 feet in length, and confifting of 34 arches.

The bridge at Blenheim confifts of three arches, the chief of which fpans 101 feet 6 inches.

Near Old Aberdeen there is a bridge over the river Don, very much celebrated. It is in the Gothic tafte. There is alfo a remarkable bridge called Sarah or Ifland bridge, built over the Liffey above Dublin, in the year 1792, by Mr. Alexander Stevens, a mafon from Edinburgh: it confifts of a fingle elliptical arch 106 feet fpan, and only rifing 22 feet; it is therefore fix feet wider than the Rialto at Venice, and one foot lefs in height.

But the moft extraordinary bridge in Great Britain is, doubtlefs, that over the river Taff, near Llantrifsent, in Glamorganfhire, called in Welfh *Pont y ty Prydd*. This is the work of William Edwards, an uneducated mafon of the country, who was only indebted for his fkill to his own induftry and the power of his genius. He had engaged, in 1746, to build a new bridge at this place, which he executed in a ftyle fuperior to any thing of the kind in this or any part of Wales, for neatnefs of workmanfhip, and elegance of defign. "It confifted of three arches, elegantly light in their conftruction. The hewn ftones were excellently well dreffed and clofely jointed. It was admired by all who faw it. But this river runs through a very deep vale that is more than ufually woody, and crouded about with mountains. It is alfo to be confidered, that many other rivers of no mean capacity, as the Crue, the Bargoed Taff, and the Cunno, befides almoft numberlefs brooks that run through long, deep, and well-wooded vales or glens, fall into the Taff in its progrefs. The defcents into thefe vales from the mountains being in general very fteep, the water in long and heavy rains collects into thefe rivers with great rapidity and force, raifing floods, that in their defcriptions would appear abfolutely incredible to the inhabitants of open and flat countries, where the rivers are neither fo precipitate in their courfes, nor have fuch hills on each fide to fwell them with their torrents. Such a flood unfortunately occurred after the completion of this undertaking, which tore up the largeft trees by the roots, and carried them down the river to the bridge, where the arches were not fufficiently wide to admit of their paffage. Here, therefore, they were detained. Brufh-wood, weeds, hay, ftraw, and whatever lay in the way of the flood, came down, and collected about the branches of the trees, that ftuck faft in the arches and choaked the free current of the water. In confequence of this obftruction to the flood, a thick and ftrong dam, as it were, was thus formed. The aggregate of fo many collected ftreams being unable to get any further, rofe here to a prodigious height, and, with the force of its preffure, carried the bridge entirely away before it. William Edwards had given fecurity for the ftability of the bridge during the fpace of feven years; of courfe he was obliged to erect another, and he proceeded on his duty with all poffible fpeed. The bridge had only ftood about two years and a half. The fecond bridge was of one arch, for the purpofe of admitting freely under it whatever incumbrances the floods might bring down. The fpan or chord of this arch was 140 feet, its altitude 35 feet, the fegment of a circle whofe diameter was 170 feet. The arch was finifhed, but the parapets not yet erected, when fuch was the preffure of the unavoidably ponderous work over the haunches, that it fprung in the middle, and the key-ftones were forced out. This was a fevere blow to a man who had hitherto met with nothing but misfortune in an enterprife which was to eftablifh or ruin him in his profeffion. William Edwards, however, poffeffed a courage which did not eafily forfake him; he engaged in it a third time, and by means of cylindrical holes through the haunches, fo reduced their weight, that there was no longer any danger from it. The fecond bridge fell in 1751; the third, which has ftood ever fince, was completed in 1755." (Mr. Malkin's Tour in South Wales.) The prefent arch is 140 feet in fpan, and 35 feet high, being a fegment of a circle of 175 diameter. In each haunch there are three cylindrical openings running through from fide to fide; the diameter of the loweft is nine feet, of the next fix feet, and of the uppermoft three feet. The width of the bridge is about

eleven feet. To ſtrengthen it horizontally, it is made wideſt at the abutments, from which it contracts towards the centre by ſeven off-ſets, ſo that the road-way is one foot nine inches wider at the extremities than at the middle.

The bridges of Weſtminſter and Blackfriars, over the river Thames at London, are among the fineſt ſtructures of the kind in Europe. The former is 1220 feet long, and 44 feet wide, having a commodious broad footpath on each ſide for paſſengers. It conſiſts of thirteen large, and two ſmall arches, fourteen intermediate piers and two abutments. The length of each abutment is 76 feet; the opening of each of the ſmaller arches is 25 feet; the ſpan of the firſt of the large arches at each end is 52 feet, of the next 56 feet, and ſo on increaſing by four feet at a time to the centre arch, the ſpan of which is 76 feet. The two piers of the middle arch are 17 feet wide, and the others decreaſe equally on each ſide, by one foot at a time, every pier terminating with a ſalient right angle againſt either ſtream. The arches are ſemi-circular, and ſpring from about the height of two feet above low water. The breadth of the river in this place is about 1220 feet, and the water-way through the bridge amounts to 870 feet. The bridge was begun in 1738, and opened for paſſengers in 1750, at a neat expence of 218,800l. It is conſtructed of the beſt materials, and in a neat and elegant taſte; but the arches are too ſmall in proportion to the quantity of maſonry.

Blackfriars bridge, nearly oppoſite to the centre of the city of London, was begun in 1760, and completed in ten years and three quarters, at a neat expence of 152,840l. It is an exceedingly light and elegant ſtructure; but, unfortunately, the materials do not ſeem to be of the beſt kind, as many of the ſtones in the piers are decayed. The bridge conſiſts of nine large, handſome, and nearly elliptical arches; the central arch is 100 feet wide, and the four arches on each ſide, reckoning towards the ſhores, decreaſe gradually, being 98, 93, 83, and 70 feet reſpectively, leaving a water-way of 788 feet. The whole length from wharf to wharf is 995 feet, the breadth of the carriage-way 28 feet, and that of the raiſed foot way on each ſide ſeven feet. The upper ſurface of the bridge is a portion of a very large circle, which forms an elegant figure, and admits of convenient paſſage over it. On each pier there is a receſs or balcony, with two Ionic columns and pilaſters, which ſtand on a circular projection of the pier above high water mark. The bridge is rounded off at each extremity to the right and left, in the form of a quadrant of a circle, rendering the acceſs commodious and agreeable. This edifice muſt be regarded as a fine ſpecimen of Mr. Mylne's ingenuity and judgment, though the method of conſtruction has never been made public.

Beſides the bridges already mentioned, there are many other neat and elegant ſtructures in different parts of Great Britain and Ireland. The bridge over the Tees at Winſton in Yorkſhire, was deſigned by ſir Thomas Robinſon, and built by John Johnſon, a common maſon at Walſingham, in the year 1762. It conſiſts of a ſingle arch 108 feet 9 inches ſpan; is built of rubble-ſtone; and coſt only 500l. An elegant ſtone bridge has lately been built over the Tweed at Kelſo, upon the plans and under the direction of Mr. John Rennie. This has five elliptical arches of 72 feet ſpan each; is quite level at top. It has two Doric pilaſters, which ſtand on a circular projection of the pier, with a ſimple block cornice. The coſt of this bridge was about 13,000l. excluſive of the roads at each end, which coſt about 3000l. more, in all 16,000l.

The bridge over the Peaſe, or rather Peaths, on the road from Dunbar to Berwick upon Tweed, is rather an uncommon ſtructure. This bridge croſſes a deep ravine called the Peaths. It conſiſts of four ſemi-circular arches. That at the eaſt ſide of the ravine is 54 feet ſpan; the ſecond 55 feet; the third 52 feet, and the further or weſtern arch 48 feet. The height of the bridge, from the bottom of the ravine to the ſurface of the road, is 124 feet. The ſituation is beautiful, and has a moſt romantic appearance. It was deſigned and built by the late Mr. David Henderſon, architect in Edinburgh, and does him conſiderable credit.

The aqueduct bridge, conſtructed by Mr. Rennie on the river Lune at Lancaſter, is one of the moſt magnificent works of the kind which has been erected for the purpoſes of navigation. At the place where it is built, the water is deep and the bottom bad. It conſiſts of 5 arches of 70 feet ſpan each, and about 39 feet above the ſurface of the water. It has a handſome cornice, and every part of it is finiſhed in the beſt manner. The foundations are laid at the depth of 20 feet under the ſurface of the water, and ſtand on a flooring of timber, ſupported by piles. The foundation alone coſt 15,000l. The ſuperſtructure coſt above twice that ſum, although the ſtone was found within about a mile and a half of the place where the aqueduct was built. Barges of 60 tons burthen navigate the canal. The total height from the ſurface of the river to the ſurface of the canal is 51 feet.

It may be obſerved in this place, that the Romans always, without any exception that we are acquainted with, made their arches either of a ſemi-circle, or of a leſſer ſegment of a circle. The vouſſoirs were generally included between two concentric curves, on which account theſe are called extradoſſed arches. The earlier Italian architects followed the example of the Romans in the forms of their arches, which are either ſemicircular, or of a ſmaller ſegment, called by them *arco intiero*, and *arco ſcemo*, from which term our workmen have taken that of *ſkeme arch*. Elliptical arches are very much uſed by the engineers of France, moſt of the bridges in that country being in this manner. The French diſtinguiſh their arches into three kinds, *l'arc plein-ceintre*, *l'arc ſurhauſſé*, and *l'arc ſurbaiſſé*; the firſt is a ſemi-circle, the ſecond higher, and the third lower than a ſemi-circle, being formed by the greater or ſmaller axis of an ellipſis; in practice, however, theſe are generally compoſed of ſeveral arcs of circles of different diameter, as in this caſe the joints are more eaſily traced. The arcs ſurbaiſſés are alſo called *anſe de panier*. The *arc bombé* is an arc ſurbaiſſé, formed by a ſegment of a circle.

The ancients always laid their wrought ſtones without mortar between the joints, frequently uſing iron cramps to connect them more firmly together. Their large arches, and thoſe which had to bear very great weights, were compoſed of ſeveral ranks of vouſſoirs extradoſſed, and breaking joint, as is ſeen in the great cloaca of Rome, and in ſeveral bridges and aqueducts. Modern architects, however, generally uſe only one rank of vouſſoirs, each of which is terminated at top by a horizontal joint, and laterally by a perpendicular joint, for the purpoſe of ranging better with the courſes of the haunches and ſpandrels.

The decoration of bridges ought to be ſimple and large, their beauty conſiſting chiefly in the proportion of the voids and ſolids, the contour of the arches, and apparent ſtrength and ſolidity, together with boldneſs of conſtruction. However, many modern architects have carried ſimplicity to exceſs, particularly in Paris, where the arches of all the bridges are plain, and without any member of architecture. A happy introduction of ruſtic work of various forms and ſizes breaks the monotony of the large maſſes, and enriches the edifice. This method was often employed by the ancients, and we never find that they neglected to ornament the arches of their bridges with archivolts more or leſs rich.

Palladio, in all his designs of bridges, has never omitted this simplest and best decoration of arches. Cornices and ballustrades also are both useful and ornamental in these structures.

Generally speaking, large arches are more expensive than smaller. In a bridge lately designed over a river, wherein the foundations were very difficult to construct, one design with three arches of 116 feet each, was estimated at 13,174l. and another of five arches of the same kind was estimated at 12,041l., which was contracted for and built for the above sum.

Wooden bridges now demand our attention. The simplest case of these edifices is that in which the road-way is laid over beams placed horizontally, and supported at each end by piers or posts. This method, however, is deficient in strength and width of opening: it is therefore necessary, in all works of any magnitude, to apply the principles of trussing, as used in roofs and of arches. Wooden bridges of this kind are stiff frames of carpentry, in which, by a proper disposition, beams are put, so as to stand in place of solid bodies, as large as the spaces which the beams enclose; and thus, two or three or more of these are set in abutment with each other, like mighty arch stones.

Palladio has given several very elegant designs of wooden bridges, which he thus describes. The bridge of the Cismone. The Cismone is a river, which, falling from the mountains that divide Italy from Germany, runs into the Brenta a little above Bassano. And, because it is very rapid, and great quantities of timber are sent down it by the mountaineers, it was resolved to make a bridge there, without fixing any posts in the water, which were liable to be carried away by the violence of the current, and the shock of the stones and trees that continually came down. The invention of this bridge, (says Palladio,) is, in my opinion, very worthy of attention, as it may serve on all occasions where these difficulties may occur, and because that bridges thus made are strong, beautiful, and commodious; strong, because all their parts mutually support each other; beautiful, because the texture of the timbers is very agreeable; and commodious, being even, and in the same line with the remaining part of the street. The river where this bridge was erected is 100 feet wide; this width is divided into six equal parts; and at the end of each part, excepting at the banks, which are strengthened with pilasters of stone, the beams are placed, that form the breadth of the bridge, upon which, a little space being left at their ends, were placed other beams lengthways, which form the sides. Over these, directly upon the first, the *colonelli* (king-posts) were disposed on each side; these king-posts are connected to the beams which form the breadth of the bridge by means of irons passing through the projecting ends of the beams, and bolted and pinned through both. See *fig.* 1. *Plate* XXXII. of *Architecture*.

Palladio proceeds to describe three other methods of constructing wooden bridges without posts in the water, like the bridge over the Cismone. The bridges after the first method are to be made in this manner: the banks being strengthened by pilasters as necessity shall require, one of the beams forming the breadth of the bridge is to be placed at some distance from it, then the first strut is to be placed with one end upon the pier, and the other end abutting against the first queen-post, which is to be connected with the beams by irons. Then the second beam for the breadth is to be placed at a distance equal to the space between the first beam and the pier, which is to be supported in like manner with a strut and queen-post, and thus proceeding as far as is required, observing to have a king-post in the middle of the length in which the struts meet both ways, and with collar beams between all the posts which stiffen and support the whole construction. Bridges after this manner are to be wider at the extremities, and contract towards the middle. See *fig.* 2. *Plate* XXXII. of *Architecture*.

The invention of the following bridge has the upper part which supports the weight in the form of a polygon, inscribed in a flat segment of a circle; the beams forming the breadth of the road-way are upheld by king-posts and irons, and the whole stiffened and supported by braces crossing one another between the king-posts. Struts at each end, reaching from the piers to the first beams, are also added to shorten the bearing, and increase the strength of the fabric. See *fig.* 1. *Plate* XXXIII. of *Architecture*.

The third design may be made with a greater or smaller arch than is here represented. The height of the bridge, in which are placed the braces between the king-posts, or rather radii, is to be an eleventh part of the span. (See *fig.* 2. *Plate* XXXIII. of *Architecture*.

Mr. Coxe, in the first volume of his Travels, has slightly described a very singular bridge at Wittingen, in Swisserland, the construction of which is quite simple. The span is 230 feet, and it rises only 5. The sketch (*fig.* 3. *Pl.* XXXIII.) will make it sufficiently intelligible. ABC is one of two great arches approaching to a Catenarian shape, built up of 7 courses of solid logs of oak, in lengths of 12 or 14 feet, and 16 inches or more in thickness. These are all picked of a natural shape, suited to the intended curve; so that the wood is nowhere cut across the grain to trim it into shape. These logs are laid above each other, so that their abutting joints are alternate, like those of a brick wall; or, in the language of the workmen, they *break joint*. It is indeed a wooden wall, simply built up by laying the pieces upon each other, taking care to make the abutting joints as close as possible. They are not fastened together by pins or bolts, but held together by iron straps, which surround them at the distance of five feet from each other, where they are fastened by bolts and keys. These two arches being erected, and well butted against the rock on each side, were freed from their supports, and allowed to settle. They are so placed that the intended road *abc* intersects them about the middle of their height. The roadway is supported by cross joists, which rest on a long horizontal summer-beam; and this is connected with the arches on each side by uprights bolted into them. The whole is covered with a roof, which projects over the arches on each side, to defend them from the weather. Three of the spaces between these uprights have struts, or braces, which give the upper work a sort of trussing in that part. This bridge is of a strength much more than adequate to support any load that can be laid upon it; though it is manifest, by the attempt to truss the ends, that it was the contrivance of a person ignorant of principle. It was the work of one Ulrich Grubenhamm, of Tuffen, in the canton of Appenzel, a carpenter without education, but celebrated for several works of the same kind.

At Schaffhausen, in Swisserland, where the Rhine flows with great rapidity, several stone bridges had been destroyed, when, in 1754, Grubenhamm offered to throw a wooden bridge of a single arch across the river, which is nearly 390 feet wide. The magistrates, however, required that it should consist of two arches, and that he should, for that purpose, employ the middle pier of the last stone bridge, which would divide the new one into two unequal arches of 172 and 193 feet span. The carpenter did so; but contrived to leave it a matter of doubt, whether the bridge is at all supported by the middle pier. It was erected on a plan nearly similar to the Wittengen bridge, at the expence of about 8000l. ster-

ling. Travellers inform us, that it ſhook if a man paſſed over it; yet waggons heavily laden alſo went over it without danger. We are ſorry to add, that this curious bridge was burnt by the French when they evacuated Schaffhauſen, in April 1799.

Beſides the wooden bridges already deſcribed, there are ſeveral elegant and well conſtructed edifices in Great Britain; the moſt eminent of which was that at Walton-upon-Thames. This bridge conſiſted of three wooden arches, and five brick arches at each end; the middle arch was 130 feet in ſpan, with a riſe of 28 feet, conſtructed of three principal ribs, framed in the manner repreſented in *Plate* XXXIV. of *Architecture*. It was the deſign of the ingenious carpenter, Mr. Etheridge.

Iron bridges. Iron being the moſt abundant, cheap, and generally uſeful of all metals, has of late been employed in many works where great ſtrength was required in proportion to the weight of the material: hence cylinders, beams, and pumps for ſteam engines, boats, and barges for canals and navigable rivers, beams and pillars for warehouſes, and other large buildings, and at length bridges have been conſtructed of iron.

Iron bridges are the excluſive invention of Britiſh artiſts. The firſt that has been erected on a large ſcale is that over the river Severn, at Coalbrook Dale, in Shropſhire. This bridge is compoſed of five ribs, and each rib of three concentric arcs connected together by radiating pieces. The interior arc forms a complete ſemicircle, but the others extend only to the cills under the roadway. Theſe arcs paſs through an upright frame of iron at each end, which ſerves as a guide; and the ſmall ſpace in the haunches between the frames and the outer arc is filled in with a ring of about ſeven feet diameter. Upon the top of the ribs are laid caſt iron plates, which ſuſtain the roadway. The arch of this bridge is 100 feet 6 inches in ſpan; the interior ring is caſt in two pieces, each piece being about 70 feet in length. It was conſtructed in the year 1779, by Mr. Abraham Darby, iron maſter at Coalbrook Dale, and muſt be conſidered as a very bold effort in the firſt inſtance of adopting a new material. The total weight of the metal is $378\frac{1}{2}$ tons.

The ſecond iron bridge, of which the particulars have come to our knowledge, was that deſigned by Mr. Thomas Payne, author of many political works. It was conſtructed by Meſſrs. Walkers at Rotherham, and was brought to London, and ſet up in a bowling-green at Padington, where it was exhibited for ſome time. After which it was intended to have been ſent to America; but Mr. Payne not being able to defray the expence, the manufacturers took it back, and the malleable iron was afterwards worked up in the conſtruction of the bridge at Wearmouth.

The third iron bridge of importance erected in Great Britain, was that over the river Wear, at Biſhop Wearmouth, near Sunderland, the chief projector of which was Rowland Burdon, eſq. M. P. As this is the moſt conſiderable ſtructure of the kind, it may be proper to give a brief ſketch of its hiſtory. In conſequence of the increaſing trade and population of Sunderland and the two Wearmouths, the ancient ferry, which was almoſt in the middle of the harbour had become very inſufficient and unſafe, ſo that, beſides frequent delays and diſappointments, ſeveral inſtances had occurred of the loſs of lives. About the year 1790, in which Mr. Burdon was returned to parliament by the county of Durham, ſome gentlemen intereſted in the welfare of the town and neighbourhood of Sunderland, united for the purpoſe of removing the evils ariſing from the ferry, and Mr. Burdon was appointed one of the committee. Conceiving at firſt that a ſtone bridge would be proper, they began to adopt meaſures for its erection. An architect was choſen to carry on the neceſſary works, who in due time produced plans, eſtimates, and a model of the intended edifice. But as the work was of conſiderable magnitude and importance, it was thought expedient to refer the deſign to the opinion of ſome gentlemen of celebrity for ſcientific and practical knowledge in and near the metropolis; their report being unfavourable, the ſcheme of erecting a ſtone bridge was abandoned. The committee, however, being now warmly engaged in the buſineſs, continued to proſecute their inquiries; and Mr. Burdon in particular being frequently called by his parliamentary duty to London, was very diligent in his endeavours to obtain information and hints from various quarters, as to the peculiar advantages and diſadvantages of different materials, as well as of various modes of conſtruction. Mr. Burdon had the good fortune to be aſſiſted in the maturing of his plans by Mr. Thomas Wilſon, a truly ingenious man, and at the ſame time to learn much of the conſtruction of iron bridges from Meſſrs. Walkers, of Rotherham, ſo that at length he became perſuaded that iron would be the moſt proper material of which to form the propoſed bridge. He thought it beſt, however, to adhere to the ancient conſtruction, by dividing the arch into portions in the manner of arch ſtones, and taking advantage of the ductility and tenacity of iron to produce an arch of that metal at leaſt fifteen times lighter than a correſponding arch of ſtone, and capable of being put together upon an ordinary ſcaffolding, inſtead of an accurate centre, in a much ſhorter ſpace of time.

Mr. Wilſon, in conjunction with Meſſrs. Walkers, conſtructed and ſet up an experimental rib at Rotherham, which being found to anſwer expectation, the ſucceſs of the experiment was communicated by Mr. Burdon to the town of Sunderland and the county; and his propoſition for the erection of an iron bridge was acceded to. The firſt ſtone was laid in September, 1793; and Mr. Wilſon was appointed to the ſuperintendance of the work. The iron-work was caſt by Meſſrs. Walkers, of Rotherham, and the arch was turned upon a very light but firm ſcaffolding, ſo judiciouſly conſtructed that not any interruption was given to the paſſage of the numerous veſſels which navigate the buſy river of Sunderland The mode of bracing the ribs was ſo ſimple and expeditious, that the whole was put together and thrown over the river in ten days; the ſcaffolding was immediately removed, and the bridge opened for general uſe on the 9th of Auguſt, 1796.

During the period occupied in erecting the bridge, Mr. Burdon took out a patent to ſecure the invention of "a certain mode or manner of making, uniting, and applying caſt iron blocks to be ſubſtituted in lieu of key-ſtones, in the conſtruction of arches." He thus proceeds to deſcribe his invention, which "conſiſts in applying iron or other metallic compoſitions to the purpoſe of conſtructing arches upon the ſame principle as ſtone is now employed, by a ſubdiviſion into blocks eaſily portable, anſwering to the key-ſtones of a common arch, which being brought to bear on each other gives them all the firmneſs of the ſolid ſtone arch, whilſt, by the great vacuities in the blocks, and their reſpective diſtances in their lateral poſition, the arch becomes much lighter than that of ſtone, and by the tenacity of the metal the parts are ſo intimately connected that the accurate calculation of the extrados and intrados, ſo neceſſary in ſtone arches of magnitude, is rendered of much leſs conſequence. *Fig.* 4. *Plate* XXXIII. of *Architecture* repreſents a block of caſt iron, five feet in depth from A to A, and four inches in thickneſs, having three arms B, B, B, and making a part of a circle or ellipſis; the middle arm is two feet in length from B to C, and

the other two are in proportion. On each side of the arms are grooves (three quarters of an inch deep, and three inches broad) for the purpose of receiving malleable or bar-iron, and in each arm are two bolt holes, D. *Fig.* 2. represents two of these blocks placed together, and the joints confined to their respective positions by the bar-iron on each side of the arms as at E, E, E, which, with other similar blocks so united and bearing upon each other, become a rib. *Fig.* 3. and F, F, *fig.* 2. are hollow tubes six feet long, and four inches in diameter, having shoulders at each end, with holes answering to those of the blocks; G is a block of another rib connected with the former by the tubes F, F, placed horizontally. Through the holes in the shoulders and arms of the block and bar-iron are bolts, fastened with cotterels or forelocks, as at H, H, H, H. The blocks being united with each other in ribs, and the ribs connected and supported laterally by the tubes as above described, the whole becomes one mass, having the property of key stones cramped together." This extract serves to explain the more minute parts of the construction: a few words more will describe the structure itself.

The bridge consists of a single arch, whose span is 236 feet; and as the springing stones at each side project two feet, the whole opening is 240 feet. The arch is a segment of a circle of about 444 feet diameter, its versed sine is 34 feet, and the whole height from low water about 100 feet, admitting vessels of from two to three hundred tons burthen to pass under, without striking their masts. A series of one hundred and five blocks form a rib, and six of these ribs compose the breadth of the bridge. The spandrels, or the spaces between the arch and the roadway, are filled up by cast-iron circles, which touch the outer circumference of the arch, and at the same time support the roadway, thus gradually diminishing from the abutments towards the centre of the bridge. There are also diagonal iron bars, which are laid on the tops of the ribs, and extended to the abutments to keep the ribs from twisting. The superstructure is a strong frame of timber planked over to support the carriage-road, which is composed of marl, lime-stone, and gravel, with a cement of tar and chalk immediately upon the planks, to preserve them. The whole width of the bridge is 32 feet. The abutments are masses of almost solid masonry, twenty-four feet in thickness, forty-two in breadth at bottom, and thirty-seven at top. The south pier is founded on the solid rock, and rises from about twenty-two feet above the bed of the river. On the north side the ground was not so favourable, so that it was necessary to carry the foundation ten feet below the bed. The weight of the iron in this extraordinary fabric amounts to 260 tons; 46 of these are malleable, and 214 cast. The entire expence was 27,000l.

From this account of the bridge across the Wear, the attentive reader will see much to admire in its construction: it is not, however, totally free from defects. We conceive that the spandrels are very improperly filled up. It is true, that it is done in such a manner as is exceedingly light and pleasing to the eye; but the iron hoops may, we think, be easily compressed at the points of contact, and changing their shape will oppose very little resistance. As the arch forms so small a portion of a circle (about 64¼ degrees), the weight at the spring of the arch need not, according to the theory of equilibration, be double to that at the crown, to support, without danger of rising, any pressure arising from the mass of the structure itself: but in so flat and light an arch, an overload on any part must have a great tendency to bend it, and consequently tend considerably to break it, at a distant part, with all the energy of a long lever: we think, therefore, that a better form might have been adopted than what has been put in practice at Wearmouth bridge.

The third iron bridge is that over the Severn at Buildwas, about two miles above Coalbrook Dale. An old stone bridge of three narrow arches having been carried away by a high flood in 1795, the present iron bridge was planned and built by the Coalbrook Dale Company, under the superintendance of Mr. Thomas Telford, the county surveyor, in 1796. It consists of a single arch, 130 feet in span, the rise from the springing to the soffite being 27 feet; and as it was thought necessary to keep the roadway as low as possible, the outside ribs are made to go up as high as the railing; they are connected with the ribs that bear the covering plates, by means of pieces of iron dovetailed in the form of king-posts. The plates which compose the covering over the lower ribs, are cast with deep flaunches; they are laid close to each other, and form an arch of themselves. These side ribs, or arches, would have added much more to the strength of the bridge than they now do, had the materials been of a substance that would not expand or contract; but that not being the case, they, in warm weather, when they expand, rather tend to derange the other parts of the bridge than strengthen it; and the appearance of the whole is by no means pleasing.

About the same time that the bridge at Buildwas was erected, an iron bridge was thrown over the river Teme in Herefordshire. Its parts were so slender and ill-disposed, that no sooner was the wooden centre taken away than the whole tumbled into the river.

The splendid example of the bridge at Wearmouth gave an impulse to public taste, and caused an emulation among artists, which has produced many examples and more projects of iron bridges. The Coalbrook Dale Company have constructed several, among which is a very neat one over the river Parrot at Bridgewater. Mr. Wilson, the engineer, employed by Mr. Burdon, has also built several, and has lately finished a very elegant one over the river Thames, at Staines, which is by far the most complete in design, as well as the best executed, of any that has hitherto been erected. This bridge consists of a single arch, 181 feet in span, and 16 feet 6 inches in rise, being a segment of a circle of 480 feet. The blocks, of which the ribs are composed, are similar to those in the Wearmouth bridge, except that these have only two concentric arcs instead of three, as at the latter. The arcs are cast hollow, and the blocks connected by means of dowels and keys; thus obviating the great defect observed at Wearmouth, of having so much hammered iron exposed to the action of the air. Four ribs form the width of the arch, which are connected together by cross-frames. The spandrels are filled in with circles, which support a covering of iron plates an inch thick: on this is laid the roadway 27 feet wide. Two hundred and seventy tons are the weight of the iron employed in the bridge, and three hundred and thirty of the roadway.

For further practical details on the construction of bridges, the reader is referred to the articles FOUNDATIONS *in Water*, CAISSON, COFFERDAM, &c.

BRIDGES, *Theory of*. In considering the theory of bridges, the first objects of enquiry are, the nature of an arch, and the principles on which depend its stability and permanence. It will be seen, by referring to the article ARCH in this dictionary, that we have adopted the opinion of those mathematicians who conceive that an arch is kept in equilibrium, or from falling, by the weight or vertical pressure of the superincumbent wall or mass. The principles on which they proceed, have now obtained the name of *the theory of Equilibration*.

It will be readily admitted, by those who attend to these subjects, that whatever properties may be shewn to relate to a geometrical or lineal arch, considered without thickness, and of its superincumbent plane, may be easily and safely transferred to a real arch of solid materials, and the heavy matter sustained by it; for it is manifest that a solid arch may be conceived either to be generated by the motion of a linear arch, and its plane in a direction perpendicular to that plane, or to be made up of an indefinite number of such equal linear arches and corresponding planes: and in either case, what is shewn to obtain with respect to the former, may without hesitation be applied to the latter. This the reader will keep in mind.

The first hint of a principle which we recollect, is contained in Dr. Hooke's assertion, that the figure into which a chain or rope, perfectly flexible, will arrange itself when suspended from two hooks, is, when inverted, the proper form for an arch composed of stones of uniform weight. The reason assigned for this principle is, that when the flexible festoon of heavy bodies becomes inverted, still touching one another in the same points, the force with which they press on each other in this last case, is equal and opposite to the forces with which they draw each other in the case of suspension. The curve formed by a rope, or flexible chain, of extremely small links, when thus suspended, is well known to our geometricians by the name of the *catenarian* curve; by the French it is called *la chainette*. If a curve of this kind be disposed in such a manner that its vertex shall be uppermost; and if a multitude of globes be so arranged that their centres shall be in the circumference of this curve, they will all remain motionless and in equilibrium: much more will this equilibrium subsist, if, instead of globes, we substitute thin voussoirs, having flat sides, which touch each other in directions perpendicular to the curve. In the former case, the equilibrium will be destroyed very easily, just as a globe resting on a plane surface is easily put into motion; in the latter, the equilibrium cannot be destroyed without considerable force, just as when a heavy body is placed upright on a broad flat base, it will not only stand, but will require considerable force to push it over.

Since the catenarian curve is readily described mechanically, it is no wonder that this principle of Dr. Hooke's should be very generally received; but many of those who adopted it, forgot that it could not be extensively applied, without certain modifications: these modifications, it will be seen farther on, cause this principle to coincide exactly with the true theory of equilibration. As to the contrary, it is manifest, from what we have already said, that it is only the form of a very slender arch rib of uniform thickness, and unfit for the purpose of a bridge; which requires a considerable mass of masonry to lie upon the arch and fill up the space to the roadway, thus completely destroying the equilibrium at first established in the arch itself. It would be possible, indeed, to construct a catenarian curve of equilibration, having a horizontal line for the extrados, but then the thickness of the mass above the crown of the arch must be enormous; thus, for a catenarian of 100 feet in span, and 40 feet high, the distance from the top of the arch to the horizontal extrados must have been nearly 37 feet to ensure an equilibrium. For these reasons the catenarian curve has been very seldom used in the erection of bridges.

Another principle, which was first assumed about the end of the 17th century, is, that every perpendicular column of masonry above the arch is merely kept from sliding down the arch by the next adjoining column. It is very obvious, at first sight, that this principle is not consistent with nature; it has therefore found but few advocates. When analytical expressions are deduced for the curvature of arches constructed on this principle, it is worth observing, that they coincide exactly with those which would flow from the supposition that the arch was in equilibrio, in consequence of having a fluid, with a horizontal surface, pressing upon every part of it.

A third principle is drawn from the consideration of the arch stones being frustums, or parts of wedges. This principle, we believe, originated in France, and has been presented in various forms by De la Hire, Belidor, Varignon, Parent, and other French philosophers, and lately by our ingenious countryman Mr. Atwood.

In the method now alluded to, it is considered what weight, in or upon a wedge, is balanced by forces acting against the sides; or what force such a wedge exerts both horizontally and perpendicularly to its sides; and thence it is computed what must be the position and shape of the contiguous wedges of given weights; or what must be their weights to a given shape and position, so as just to exert the adequate degree of resistance required by the first wedge; and so on, from wedge to wedge, till the whole is balanced. A mere arch constructed in this way, would remain in equilibrio as long as the constituent voussoirs had liberty to slide, without friction, down the respective inclined planes on which they lay. This method is, indeed, liable to many objections. First, this theory requires, that either the density or the magnitude of the respective voussoirs, from the crown to the foot of the arch, should keep constantly increasing in proportion to the differences of the tangents of the several angles, which the joints of the voussoirs make with the vertical axe of the curve. Now, if the architect should wish to change the density of his materials in the required proportion, we know not what materials he could use; for the density must always be very great towards the spring of the arch; and, in many cases, it must be infinitely great. If, on the other hand, the magnitudes of the voussoirs were gradually increased, it would be necessary that those at the spring, and consequently the abutments, should be immensely great, and often infinite; besides, that the wedges must be cut to different oblique angles, very difficult in execution, and totally unsafe when erected, as the acute angles would be in constant danger of flushing off. Here, too, in real practice, there would be a total want of balance, on account of the mass of masonry and rubble work, which fills the space between the arch and the road-way. But even this is not all; the arch stones cannot be made, nor indeed ought they, to act as the true mathematical wedge, the properties of which were employed in attempting to establish the equilibrium. The wedge of these theorists is supposed to have its butting sides perfectly polished, and to have its weight or other force on its back balanced by proper equivalent forces acting perpendicularly against those sides. Now this is so far from being the case in the practice of bridge-building, that architects contrive to have the butting sides of their wedges so rough as to occasion a great deal of friction between them; and to increase the adhesion of these sides the more, they introduce between them the best and strongest cement they can procure. By these means, so far from the arch stones being kept in their places only by forces perpendicular to their butting sides; and having liberty to slide along those sides, as in the wedge theory, they are absolutely prevented from the possibility of so sliding, and in a great measure kept in their places in the arch, by forces that act even perpendicular to those which the wedge theory requires. On these accounts, then, we conceive that, however specious and plausible this theory may appear on paper, it ought not to be admitted, since it is manifestly inapplicable to any case which can ever occur in real practice.

On the contrary, the theory which we have adopted, or that

given by Emerson in his fluxions, published in the year 1742, and which has been so ably and judiciously handled by Dr. Hutton in particular, is consistent with nature and with truth. This theory establishes an equilibrium among all the vertical pressures of the whole fabric contained between the soffit, or under-side of the arch, and the road-way over all. It is now very generally adopted by the most skilful engineers and architects, as the only true one; because it secures a balance in the whole of the ponderating matter, by making an equality at every point of the curve, between all the adjacent pressures when reduced to the tangential directions, or perpendicular to the joints, which are supposed to be at right angles to the curve of the arch in every part, as such structures naturally require them to be: for, if the joints be perpendicular to the curve, there will arise a lateral pressure, whose direction is not along the tangent; which, wanting a force to sustain it, will destroy the equilibrium, and some of the stones will endeavour to fly out.

When speaking of the principle advanced by Dr. Hooke, we observed, that by means of peculiar modifications, it was capable of universal application to cases occurring in practice, and was at the same time consistent with the theory we have assumed. This we shall now proceed to shew. In *Pl.* XXXVIII. *Architecture*, *fig.* 1. is *fig.* 2. *Pl.* VI. (referred to in the article ARCH) completely inverted. Let this represent a flexible chord or chain, void of gravity, hanging from the points A and G, which are fixed; at the points B, C, D, E, F, suppose weights to be suspended, (acting in the directions BH, CI, DK, &c.) proportional to the several lines B *i*, C *m*, D *n*, E *s*, and F *y*. Then the case now before us will be the complete inversion of that which is first stated in *Prob.* 1. article ARCH, the drawing forces in this instance being respectively equal and opposite to the several pressing forces in that: therefore, every thing proved there, by means of the composition and resolution of forces, will be found to obtain here, only in a contrary direction. Consequently, if the number of weights hanging from the chord ADG be indefinitely increased, it will assume a curvilinear shape, similar in its nature to the arch of equilibration, only in an inverted position; and the various theorems which relate to the weights and pressures of the standing arch, apply with equal facility and accuracy to the weights hanging from the suspended arch. Whether, therefore, we consider the standing or the hanging arch, it is equally true, that in the case of just equilibration, the column either pressing or drawing at any point of the arch is reciprocally as the radius of curvature and the cube of the sine of the angle, in which the vertical line cuts the curve in that point (Cor. 2. pr. i. ARCH); or, since the cosecant varies as the sine inversely, the column above-mentioned is reciprocally as the radius of curvature, and directly as the cube of the secant of the curve's inclination to the horizon, in the given point

But the analogy between the standing and the hanging arch has been traced out, not so much for the purpose of corroborating the true theory of equilibration, as for the sake of deducing from it a very popular and general mode of construction; strictly accurate in its principle, and yet so simple in its application, that the most illiterate artist may safely practise it. Suppose it were required to ascertain the form of an arch which shall have the span AG (*fig.* 2. *Pl.* XXXVIII. *Architecture*) and the height D 8, and which shall have a road-way of the form BEC above it. Let the outline figure ABECG be inverted, so as to form a figure A *bec* G. Suspend a fine chain of uniform thickness from the points A and G, and of such a length, that its lower point will hang a little below *d*, corresponding to D. Divide AG into a number of equal parts (the more the better) in the points 1, 2, 3, &c. and draw vertical lines, cutting the chain in the corresponding points 1, 2, 3, &c. Now take pieces of another chain, whose links are easily separated, and hang them on at all the points 1, 2, 3, &c. of the chain A *d* G: trim these pieces of chain, by taking off links at some places, and hanging on at others, till their lower ends all coincide with the inverted road-way *bec*. The greater lengths hung on in the vicinity of A and G, will pull down those points of the chain, and cause the middle point *d*, which is less loaded, to rise a little, and bring it near to its proper height. It is obvious this is an arch of equilibration for a bridge so loaded, that the weight of the arch-stones is to that of the superincumbent matter between the arch and road-way, as the weight of the chain A *d* G, is to the sum of the weights of all the little bits of chain, very nearly. But this proportion is not known before-hand; we must, therefore, proceed thus: adapt to the curve produced in this way such a thickness of the arch-stones as may be thought sufficient to ensure stability; then compute the weight of the arch-stones, and the weight of the rubbles, or other materials with which the haunches are to be filled up to the road-way. If the proportion of these two weights be nearly the same with the proportion of the weights of the chain, we may rest satisfied with the curve now found: but if it be much different, we may soon find how much should be added to, or taken from, the appended bits of chain, in order to make the two proportions equal. We shall then have a curve infinitely near to the inversion of the curve wanted. This method we can safely recommend, as we know it to have been frequently used with facility and success.

It would draw us far beyond the limits we are obliged to assign ourselves, were we to give a complete view of the theory in all its branches: those who are desirous of obtaining a more intimate acquaintance with the subject are, therefore, referred to Dr. Hutton's ingenious treatise on bridges; for our own parts, we must content ourselves with just touching upon a few of the most important particulars. Under the article ARCH, and the corresponding plate, we have given figures of the extrados, of a circular and elliptical arch of equilibration; from which it may be seen how far the extrados extends from the vertex of the curve, before it becomes unfit for a road-way by reason of its bending upwards: in this respect, it appears, that the flat ellipsis has the advantage of the circular arch; but the cycloidal arch of equilibration, though similar to these, has the advantage of both, because the extrados runs farther on, nearly parallel to the arch before it comes to the point of inflection. We should observe, however, that in many cases, even of circular or elliptical arches, the evil arising from the inflection of the extrados may be thrown off to a greater distance, by a very simple expedient: for, in an arch of equilibration, as NBH, *fig.* 3. *Pl.* XXXVIII. of *Architecture*, whose extrados is EIK SF, since the points at *m*, *n*, *o*, &c. are kept in equilibrio by the heights of the wall I *m*, K *n*, L *o*, &c. if the lines I *m*, K *n*, L*o*, &c. be divided in a given ratio, in *i*, *k*, *l*, &c. the smaller mass, under the new extrados *e*, *i*, *k*, *s*, *f*, will still secure the equilibrium. Now it is obvious, that the lower extrados runs much farther from the crown than the upper one, before it has a point of inflection: and hence appears one great advantage arising from the use of iron in bridges instead of stone. Suppose, for instance, that an arch was to be constructed, having the span AD, and height CB, and that the necessary thickness of a stone arch at the crown was BS; here it is plain, that if the road-way were made, having a practicable slope as SK *a*, it would fall far below the required extrados at KIE, and consequently, the arch, for

want of a sufficient weight over the portion $A\,m\,n$, and an equal portion on the other side of the vertex, would be in constant danger of rising in the haunches. But a bridge formed of hollow iron voussoirs would be abundantly strong, with far less thickness over the crown, as $B\,s$; and then the true extrados $e\,i\,k\,f\,f$ would, in every part, have a proper slope for a road-way; while, at the same time, the structure is in no danger of being destroyed for the want of an equilibrium in all its parts.

We have mentioned under the article Arch, what kind of arches ought to be preferred in the erection of bridges; and have shewn which are strongest: we may here observe, that if there be two arches of the same kind, with an equilibrated load over each of them, the strength of the one will be to the strength of the other reciprocally as the radii of curvature at the vertices of the two arches: hence an elliptical arch, standing on its shorter axis, will be stronger than a semicircular arch of the same span; and the semicircular arch of equilibration will be stronger than a flat elliptical arch of the same span. As to the effect of an additional weight over any part of an arch, it will vary in proportion of the horizontal distances from the extremities of the arch. Hence the greatest danger arising from an additional weight, is when it lies over the crown of the arch; for then the product of the horizontal distances from the abutments is equal to the square of the semi-span, and is the greatest that can be.

Since in any arch of equilibration, the pressure arising from the incumbent weight at any point is reduced to the direction of the tangent at that point, we have in any such arch V B, *fig.* 4. *Pl.* XXXVIII. of *Architecture*, the weight of the part V B E A, the pressure along the tangent F B, and the horizontal pressure in direction D B, respectively as the lines F D, B F, and B D, or as the corresponding lines in a triangle, whose sides are severally perpendicular to those in B D F. Hence, it is easy to find the area of the portion A E V B, thus: make $c\,v$ parallel and equal to C V, the radius of curvature at the vertex; and draw $c\,b$ perpendicular to the tangent B F, meeting $v\,b$ the perpendicular to $c\,v$ in b; then in the triangle $c\,v\,b$, $c\,v$ corresponds to D B, and $v\,b$ to D F; and the area of the parallelogram $a\,v$, having $v\,e =$ V E, is equal to the area of A B V E: in like manner, by drawing $c\,g$ perpendicular to G I, the tangent at G, we should have the parallelogram $h\,b$ equal to the portion H B over the part G B of the arch. The area of the space H E V G, between the arch and the road-way, being thus ascertained, its weight of course becomes known, and, consequently, its horizontal pressure against the abutment, as at G: for it will be, as the line $v\,g : v\,c ::$ the weight over the semi-arch : the horizontal thrust against the abutment, or a pier, at G.

But in estimating the thrust against the piers, &c. it is most common to ascertain the position of the centre of gravity of the load above the arch. Now, in cases of equilibration, this may sometimes be effected without much difficulty: for it is well known, that if a heavy body be sustained by two forces, their directions must meet, either at the centre of gravity of that body, or in a vertical line which passes through it: therefore, since the whole incumbent weight over a properly balanced arch, is sustained in equilibrio by two forces, acting in the direction of the tangents to the extreme points of the curve, the centre of gravity of the materials upon the arch will be in the vertical line which passes through the intersection of these tangents: and in most cases occurring in practice, the centre of gravity will be nearly equi-distant from the extrados and intrados of the equilibrated arch. Thus, in the curve A V B, loaded to the equilibrium, *fig.* 5. *Pl.* XXXVIII. of *Architecture*, the centre of gravity of the superincumbent mass is in the vertical line D d, passing through the intersection of the tangents A D, and B D. And the centre of gravity of the materials A V H K, between the crown and the abutment, is about the middle of the vertical line E e, passing through the intersection of the tangents A D and V i. If the arch be part of a circle. i V is the tangent of half the arch A V, which, subtracted from half the span, leaves A G = sine of A V — tangent of half A V: and since G e = versed sine of arc A V — versed sine of arc e V, we shall, by adding $\frac{1}{2}$E e to G e, have the altitude of the centre of gravity, from A C the horizontal line. If A V be a parabola, $AG = \frac{1}{3}AC$; but if it be an equilibrated curve, with a horizontal extrados, then $AG = \sqrt{\frac{VH \times CV \times R}{2\,VH + CV}}$, where R is the radius of curvature of the arch at the crown. When the arch is not justly equilibrated, other methods of finding the centre of gravity of the mass supported must be had recourse to. See Hutton on Bridges, p. 49—56. It may be worth while, however, to describe here an easy practical method, accurate enough, for most purposes: namely, to draw, on a piece of card paper, a plan of the arch, and its load; then to cut out half of it as D A B C, *fig.* 6. *Pl.* XXXVIII. of *Architecture*, and to determine experimentally the point K in the piece cut out, on which, when supported, the whole will rest; for this point will manifestly correspond with the centre of gravity.

The place of the centre of gravity being determined, we may now shew how to ascertain the thickness of a pier, necessary to support a given arch. Let A B C D, *fig.* 6. *Pl.* XXXVIII. represent the mass over half the arch; D E F G the pier. From the centre of gravity K of the mass, draw K L, perpendicular to the horizon: then the weight of the arch in the direction K L, will be to the horizontal push, or lateral pressure at A, in the direction L A, as K L to L A. For the weight of the arch in the direction K L, the horizontal push in the direction L A, and the oblique push in the direction K A, will be as the three sides K L, L A, K A. So that if A denote the weight or area of the arch, then $\frac{LA}{KL}$. A, will be its force at A in the direction L A; and $\frac{LA}{KL} \times GA \times A$, its effect on the lever G A, to overset the pier, or to turn it about the point F. Again, the weight of the pier will be as its area $EF \times FG$, and, supposing the load over the arch and the pier to be of similar materials, $EF \times GF \times \frac{1}{2}FG$ or $\frac{1}{2}EF \times FG^2$, is the effect on the lever $\frac{1}{2}$FG to prevent the pier from being overset. Here it is supposed, that the length of the pier, from point to point, is the same as the thickness of the arch, and that the centre of gravity of the pier falls in the vertical plane bisecting F G. Now, that the pier and the arch may be in equilibrio, the two effects just stated must be equal: therefore, we have $\frac{1}{2}EF.FG^2 = \frac{LA}{KL} \times GA \times A$, from which it follows, that the thickness of the pier is $FG = \sqrt{\frac{2\,GA \cdot AL}{EF \cdot KL}} \times A$.

In the above investigation, in is supposed, that the whole of the pier is out of water: but if any part of it be immersed in water, that part will lose so much of its weight as is equal to its bulk of water, if the water can get below the pier or into the joints. This, however, may easily be brought into the calculation. By applying the above theorem to the several cases which may arise, the thickness of the pier may be found, so that it shall *just* balance the spread

or shoot of the arch, independent of any arch on the other side of the pier. But the weight of the pier ought a little to preponderate, or exceed in effect, the shoot of the arch; and, therefore, the thickness ought to be taken a little more than what the theorem will give: indeed, in most cases occurring in practice, the thickness must be between the *fifth* and the *seventh* part of the span of the arch.

The only remaining consideration in the theory, relates to the form of the ends of a pier, so as to afford the least resistance to the force of the stream of water. Now, it may be found by a fluxional process, that if the water strike every part of the pier with equal velocity, the end of the pier should be a right-lined triangle, when the force of the water upon it is the least possible: when the variably increased velocity, as in the case of a flood, is used, the form of the ends comes out a little curved. One third of the absolute force is taken off, by making the ends of the pier semicircular; $\frac{11}{20}$ would be taken off, if the ends were parabolic; but when the ends are right angled triangles, with the right angles pointed into the stream, the absolute force of the water upon the pier is reduced to one half; and an acute angle pointed to the stream will reduce its force still more. But in rivers, on which heavy craft navigate, and pass the arch, it is generally better to make the ends nearly semicircular: for, although it does not divide the water so well as the triangle, yet it will bear the shock of the vessels better, and, at the same time, be more likely to turn them off towards the middle of the arch.

Bridge, in *Gunnery*, the two pieces of timber which go between the two transums of a gun-carriage, on which the bed rests.

Bridge, in the *Military art*. *Flying bridge*, *pont volant*, or *pons ductarius*, signifies a bridge constructed of pontoons, leather boats, beams, hollow casks, sheaves of rushes, blown bladders, called *ascogephyri*, or the like, laid upon a river, or marshy and boggy ground, and covered over with planks, for the passage of a body of troops.

Flying bridge, *pont volant*, taken in a more particular signification, denotes a bridge composed of several boats, connected by a flooring of planks, and surrounded by a ballustrade or railing. It is furnished with one or more masts, to which is fastened a strong cable, supported at proper distances by boats, and extending to an anchor to which the other end is made fast, in the middle of the water. By this contrivance, the bridge becomes moveable, like a pendulum, from one side of the river to the other, without other help than a rudder. Such bridges were formerly sometimes constructed of two stories, for the quicker passage of a great number of men, or that both infantry and cavalry might pass at the same time. The use of this kind of flying bridge is, however, attended with great difficulty and danger, and subject to the most fatal accidents. An unfortunate instance of this occurred at the evacuation of Nimeguen in the campaign of 1794, where, while the Dutch garrison were occupied in crossing the river, an unlucky shot from the French batteries carried away the top of the mast, and the bridge swinging round to the enemy's side of the Waal, above 400 of the garrison were immediately made prisoners. Those who remained in the tower, to a much greater number, bereft of the means of escape, surrendered to the besiegers.

Another kind of *flying*, or *floating bridge*, is formed of two small bridges laid over one another in such a manner, as that the uppermost stretches and runs out by the assistance of cords drawn through small pullies, placed along the sides of the undermost bridge, which is thus pushed forward, till the farther extremity of it rests against the place it is intended to be fixed upon.

When these two bridges are extended to their utmost length, so that the two middle ends meet, they should not be above four or five fathoms long; for if longer, they will break. Their chief use is for surprising out-works, or fortified posts that have but narrow moats. In the memoirs of the Royal Academy of Sciences, we find a new contrivance of a floating bridge, which lays itself on the other side of the river. Vide Hist. Acad. R. Scienc. an. 1713, p. 104.

Draw-bridge, or *pons subductarius*, is a bridge fastened at one end with hinges, so that the other end may be lifted up or let down by some easy contrivance. The most common method is by a kind of balance called *plyers* (which see); in which case the bridge stands upright, to hinder the passage of a moat, or the like; the breadth of this bridge is usually about nine or ten feet, and its length about fifteen feet. There are others so constructed as to be drawn back, for hindering a passage, and to be thrust over again for affording a passage. Others open in the middle, half turning to one side, and the other half to the other, being joined again at pleasure; but these are subject to an obvious inconvenience, as one half of them remains on the enemy's side. The marquis de L'Hopital has given the construction of a curve, in which a weight will always be a counterbalance to a draw-bridge; which the younger Bernouilli has shewn to be no other than the cycloid. Act. Erud. Lipf. an. 1695.

Drawbridges are likewise frequently used on canals, navigable rivers, and wet-docks; for small canals they consist of one leaf or frame only, moveable on hinges; but for large canals, such as the Forth and Clyde canal, in Scotland, and for wet-docks, &c. they are made in two pieces which meet in the middle, forming an arch, and are raised or lowered by means of balance frames, moveable on the tops of uprights, suited in height to the magnitude of the bridge. Such bridges, however, have been found inconvenient in use, owing to the obstruction they give to the yards and rigging of ships in passing through them. This gave rise to the invention of a different sort of bridge, which, for small canals, consists of one frame or leaf only, turning on a centre or series of balls or rollers; and for large canals, or navigable rivers, they are formed of two parts, which meet in the middle. The first that have come to our knowledge are those at Cherbourg and Toulon. Neither of them, however, are so complete as those that have lately been constructed at the West India and London docks; the latter spans 40 feet, and 15 feet wide in the roadway, and is made of thin ribs of cast iron, about an inch and a half thick, turning on a number of concentric rollers, moving between two circular rings of cast iron, which are very nicely turned, and there is a flap for each leaf, which lets down by a screw, and abuts against the stone work on each side, forming the whole, when shut, into an arch, capable of carrying any weight which can ever pass over it.

The whole, though weighing 85 tons, moves with great ease, and can be opened and shut in less than three minutes, thereby occasioning very little obstruction to travellers, while vessels pass through the locks.

Bridge of communication, is a bridge made over a river, to preserve a free intercourse between two armies, or fortified places, separated by the stream.

The bridge now most generally employed, and which, by reason of its superior efficacy, has gradually almost superseded the use of all those above-mentioned, is that constructed of copper or wooden boats, fastened with stakes or anchors to the bed of the river, and covered over with

planks. Modern armies generally carry with them a number of these copper boats, or pontoons, that they may always be in readiness for throwing over bridges. Several of these being joined side by side, till they reach across the river, and planks laid over them, make all plain for the troops to march upon.

The most remote ages of antiquity furnish us with many remarkable instances of bridges of this kind. One of the earliest upon record, is that laid by Darius Hystaspes over the Ister, or Danube, in his Scythian expedition, about the year before Christ 508. Herodotus, l. iv. c. 98. Darius also crossed the Thracian Bosphorus with 700,000 men by means of a bridge of boats, the strait being five stadia, or 1008 yards in breadth. That of Xerxes in the year 480 before Christ, seven Greek stadia, or, as some estimate them, nearly a mile in length, across the Hellespont, is still more remarkable. The boat-bridges of Xerxes began at Abydos, and terminated a little below Sestus. This passage, which is the narrowest part of the strait, is only about 375½ toises, or 800 yards wide. But, as the length of the bridges is said to have been seven stadia, M. D'Anville (M de l'Acad. des Bell. Lettr. t. 28. p. 334.) has from thence inferred, that these stadia were only 51 toises, or 108 yards, each. The first bridge of Xerxes having been carried away by the force of a tempest, he substituted two others, that towards the Pontus Euxinus, consisting of 360 vessels of the largest dimensions used in the ancient navies; the other of 340. These were steadily moored by means of large anchors. Six immense cables, fastened to large piles driven into the opposite shores, extended the whole length of the bridges. Across these were laid trunks of trees, and upon them a flooring, which was covered with earth for the passage of the army. The whole was secured by a railing on each side. This contrivance is the model of most of the bridges of boats which have since been constructed, with this difference, that the vessels of Xerxes were arranged stem and stern upon the water, a plan exactly contrary to the present method. That the Persians were in the habit of constructing bridges of this kind, appears from these examples, and from another recorded by Xenophon, who mentions that of Sitace over the Tigris, composed of 27 boats. The Greeks and Romans were very expert in this part of the military science. Several bridges of boats are mentioned by Appian, in his account of the social war. That of Cæsar over the Rhine is familiar to the readers of ancient history; and in all his campaigns, we observe particular attention on the part of that celebrated commander with regard to the passage of rivers, or preserving communications by means of bridges. In the contest between the armies of Otho and Vitellius about Cremona, a bridge of this kind is noticed by Tacitus. That of Trajan over the Danube has been already mentioned. Where boats were wanting, the ingenuity and cruelty of the ancients found other expedients for overcoming the obstacles presented by the rivers to their progress. Hamilcar Barcas, in his war against the mercenaries, crossed the Macar by means of the following stratagem. He observed that when the west-north-west wind prevailed, the sand it agitated almost choaked up the mouth of the river, and formed a kind of natural bridge for the passage of his troops. He availed himself of this discovery to pass the Macar in the night, and obtain by surprise an easy victory. Sapor the Persian, by a refinement in cruelty, made use of the bodies of his prisoners to facilitate the passage of his army. (Vid. Herod. lib. iv. cap. 97, 101.—Ibid. lib. vii. cap. 33—36.—Xenophon Anab. lib. ii —Appian, de Bel. Civ.—Cæsar de Bel. Gall. lib. iv.—Tacitus, hist. lib. ii.—Dion Cassius, hist.—Polybius, lib. i.—Trebell. Poll. in Valerian.)

Of late years the laying of bridges across rivers has been greatly improved and facilitated. In the campaigns of 1799 and 1800 in particular, this branch of the military science attained that pinnacle of excellence which it will be difficult to surpass. Few objects present more varied details than the crossing a river by open force, and in presence of an enemy. In operations of this kind, localities and other physical circumstances differ so infinitely, and give rise to such numerous combinations of advantages or disadvantages, that it is impossible to lay down any given precepts which may be very applicable in all cases. What may be very proper and feasible upon one river, or at a certain season of the year, may be impracticable elsewhere, or in any other period. Sometimes the necessaries for the expedition must be transported by water; at others, by land. Rivers which have marshy banks, a smooth bed, an even current, and a muddy bottom, require totally different precautions from those with a rapid and formidable current, which are overhung with thick woods, or have a rocky bottom. The best commentary upon these several cases, will be a detailed account of the operations adopted in them.

The passages of the Rhine by the French troops at Urdingen, Neuwied, Kehl, and Diersheim; at Reichlingen, Atzmoor, and Luciestieg in Swisserland; those of the Limmat, the Danube, the Lech, the Inn, and finally of the Mincio, will evince the progress lately made in the construction of bridges of pontoons. Two of these have been treated with great precision by an engineer in the French service, whose work well deserves the attention of military men in general. (Dedon, relation des passages, de la Limmat et du Rhin. Par. 1801, 8vo.)

Under this article of *bridges* we may also mention *portable bridges*, easily taken asunder, and put together again. M. Couplet mentions one of this kind, 200 feet long, and which 40 men may carry. See Du Hamel. Hist. Roy. Acad. Scienc. l. iii. § 5. c. 4.

Pendant, or *hanging bridges*, called also *philosophical bridges*, are those which are not supported by posts or pillars, but hang at large in the air, being sustained only at the two ends or butments. Of such bridges, consisting of a single large arch, instances have been already mentioned. Bridges of this kind are used by the Spaniards for passing the torrents in Peru, over which it would be difficult to throw more solid structures either of stone or timber. Some of these hanging bridges are formed so strong and broad, that loaded mules pass along them. Ulloa. tom. i. 358. Dr. Wallis gives the design of a timber bridge, 70 feet long, without any pillars, which may be useful in places where pillars cannot be conveniently erected. Phil. Transf. N° 163, p. 714. Dr. Plott informs us, that there was formerly a large bridge over the castle-ditch at Tutbury in Staffordshire, made of pieces of timber, none much above a yard long, and yet not supported underneath, either with pillars or arch-work, or any other sort of prop whatever.

It has been already mentioned, that the ancient Romans paid particular attention to the construction and reparation of bridges; and that in the middle ages the building of bridges was reckoned among the acts of religion. By our ancient laws, *pontium reparatio*, or the reparation of bridges, was part of the *trinoda necessitas*, to which every man's estate was subject. However, by the great charter, 9 Hen. III. c. 15. no town, nor freeman shall be distrained to make bridges nor banks, but such as of old time, and of right, have been accustomed. And none can be compelled to make new bridges, where none were ever before, otherwise than by act of parliament. 2 Inst. 701. By the common law, some persons are bound to repair bridges by reason of the tenure

of their lands or tenements; and ſome by reaſon of preſcription only. 2 Inſt. 700. But if a man make a bridge for the common good of all the ſubjects, he is not bound to repair it; and if none are obliged by tenure or preſcription at common law, then the whole county or franchiſe ſhall repair it. 2 Inſt. 701. By 22 H. VIII. c. 5. it is enacted, that, as in many places it cannot be known and proved, what hundred, town, pariſh, perſon, or body politic, ought to repair bridges broken in the highways, in every ſuch caſe, the ſaid bridges, if they be without a city or town corporate, ſhall be made by the inhabitants of the county; if within a city or town corporate, then by the inhabitants of ſuch city or town corporate; if part be in one ſhire, city, or town corporate, and part in another, or part within the limits of a city or town corporate, and part without, the inhabitants of the ſhire, cities, or towns corporate, ſhall repair ſuch part as lies within their limits. The decays of bridges are preſentable in the leet, or torn. 2 Inſt. 701. By the above act, the juſtices, or four of them at the leaſt, ſhall have power to inquire, hear, and determine in the general ſeſſions, of all manner of annoyances of bridges broken in the highways, to the damage of the king's liege-people, and to make ſuch proceſs and pains upon every preſentment againſt ſuch as ought to be charged to make or amend them, as the king's bench uſually doth, or as it ſhall ſeem by their diſcretions to be neceſſary and convenient for the ſpeedy amendment of ſuch bridges. Such part of the highways as lies next adjoining to any ends of any bridges within the ſpace of 300 feet, ſhall be made and repaired as often as neceſſary; and the juſtices ſhall inquire into, and determine annoyances in ſuch highways. By 12 Geo. II. c. 29. no money ſhall be applied to the repair of bridges, until preſentment be made by the grand jury at the aſſizes or ſeſſions, of their inſufficiency, inconveniency, or want of reparation. Again, by 1 Ann. ſt. 1. c. 18. no fine, iſſue, penalty, or forfeiture, upon any preſentment or indictment for not repairing bridges, or the highways at the ends of them, ſhall be returned into the exchequer, but ſhall be paid to the treaſurer, to be applied towards the ſaid repairs, and not otherwiſe: and no preſentment or indictment for not repairing bridges, or highways at the ends of bridges, ſhall be removed by "certiorari" out of the county into another court. The charges of repairing and amending bridges, and highways at the ends of them, ſhall be paid out of the general county rate. 12 Geo. II. c. 29. The four juſtices in ſeſſion may appoint two ſurveyors, with ſalaries, to ſee the bridges amended. 22 H. VIII. c. 5. This buſineſs of ſurveying bridges is uſually annexed by the juſtices to the office of the high conſtables, with the allowance of ſalaries. The ſtat. 14 Geo. II. c. 33. gives juſtices the power of changing the ſituation of bridges, as it enables them to purchaſe lands adjoining any county bridge, for the more commodious enlarging, and convenient rebuilding the ſame. By 12 Geo. II. c. 29. juſtices, at their general or quarter ſeſſions, after preſentment made by the grand jury of bridges wanting reparation, may contract for rebuilding and repairing the ſame, for any term not exceeding ſeven years, at a certain annual ſum. They ſhall give public notice of their intention to contract, make contracts at the moſt reaſonable prices, and take ſecurity of the contractors for due performance.

If a man has toll for men or cattle paſſing over a bridge, he is to repair it. And toll may be paid in theſe caſes by preſcription or ſtatute.

By many ſpecial ſtatutes, enacted upon the occaſion, it is made felony to deſtroy bridges, &c. erected by virtue of theſe acts of parliament.

Bridge-*maſters*, are officers of the city of London, choſen by the citizens, who have certain fees and profits belonging to their office, and the care of London bridge, &c.

Bristol

BRISTOL, in *Geography*. This ſecond city of England is ſituated on the ſouthern extremity of Glouceſterſhire, and the northern of Somerſetſhire, and once formed part of both counties. It is ſeated principally on a peninſula, between the rivers Frome and Avon, and lies in 51° 30′ N. lat. 2° 46′ W. long. and is in a bearing weſt 117 miles from London, and 12 from Bath. Various conjectures have been formed relative to its ancient and preſent name. Barret, in his large hiſtory of this city, ſays it received the appellation of Caer-Oder at an early period; but is at a loſs for the origin of Oder. Caer-Brito, its original deſignation, was evidently the generic name it obtained while a protected city of the Britons, under the Roman forces, which were ſtationed at Abone in its immediate vicinity. From this it was changed to Brightſtow, or Brighticſtow, perhaps a tranſlation of Caer-Brito; or it might have taken that name from

Brightick, ſon of Algar, and great-grandſon of Alfred, who was hereditary lord of the place. Its preſent name, Briſtol, appears to have been derived from ſome early Latin writers, changing it, by way of euphony, into Briſtolina, while that of its common pronunciation, Briſtow, is evidently an abridged mode of pronouncing Brightſtow. It is a tradition, from an account which William of Worceſter gives out of a MS. he ſaw in the houſe of the Calenderies, that Briſtow was founded, or rebuilt by Brennus, ſon of Malmutius Dunwallo, who reigned a king of the Britons 380 years antecedent to the Chriſtian æra. In alluſion to which two ſtatues are placed over St. John's gate, in this city, emblematic of Brennus and Belinus, who are ſaid to have reigned conjointly after the deceaſe of their father. It is probable that a ſituation ſo eligible muſt have ſtruck the early Britons, who therefore made it a place of aſſociated habitation, previous to the Roman invaſion; however, it is evident that it was a place of importance during that period, for Gildas, as early as A. D. 430, reckons this among the fortified and eminent cities of Britain, under the name of Caer-Brito. Nennius alſo, A.D. 620, mentions it in his enumeration of 28 cities of Britain. On the dereliction of the iſland by the Romans, the Saxons overran the country and took poſſeſſion of Briſtol. Leland ſays, it was by them conſiderably increaſed; and alſo remarks, that St. Jordanus, a diſciple of St. Auguſtine, ſent by pope Gregory to convert the Saxons to Chriſtianity, preached the goſpel at Briſtol, where he died and was buried. Thus we find it a place of note at the end of the 6th century. In Domeſday book, finiſhed by command of the conqueror in 1086, the inhabitants are ſtyled burgeſſes. It was then exceeded in rate by no city, except London, York, and Wincheſter.

Early and preſent extent. The city, as firſt laid out at the conflux of the Frome and Avon, was, except on the northern part, where afterwards the caſtle was erected, inſulated by theſe rivers. The ground roſe each way to the centre, forming a pleaſant hill. It was divided into four tranſverſe ſtreets, and walled round after the courſe of the river for its better defence. At the end of each ſtreet were a fortified gate and a church, and four churches ſurrounded the croſs at the centre of the city. In this ſtate Briſtol could not exceed a mile and a half in circumference. The conflux of people drawn hither by its growing trade ſoon extended it beyond the walls, both on the Glouceſterſhire and Redcliffe ſide of the Avon. Other walls and gates therefore would become neceſſary, and it was thus further defended, before the wooden bridge was built acroſs the Avon. Leland mentions others, which he terms "Eſternavel ſecunda mœnia urbis." Indeed, the large and ſtrong caſtle, with its outworks, when completed, as it joined cloſely to the old town and the buildings on the ſouthern ſide of the river, incloſed alſo by a ſtrong wall, were great additions to the city, and thus made its circumference at leaſt two miles and a half. The acceſſion of the monaſtery of St. Auguſtine, with Gaunt's church and hoſpital to the weſt, the priory of St. James to the north-weſt, and the purchaſe of the caſtle precincts, and laying it out in ſtreets, added very conſiderably to the extent of Briſtol, towards the cloſe of the 17th century. Since that period moſt of the buildings have been erected, both in the city and ſuburbs, which bear a modern appearance, and theſe have been numerous; ſo that it may be truly ſaid, that Briſtol has increaſed, within the laſt 40 years, full a fourth. This city once formed part of the Saxon kingdoms of Weſſex and Mercia; and after the whole of England was ſubjected to one monarch, and divided into counties or ſhires, conſtituted part of the counties of Glouceſter and Somerſet, though it was generally conſidered as belonging to the latter county. It was by royal charter, temp. Edw. III. made a county of itſelf; and by other different charters, its boundaries have been extended from time to time, till they now form a line on the Glouceſterſhire ſide, of $4\frac{1}{2}$ miles and 37 perches, and on the Somerſetſhire ſide $2\frac{1}{2}$ miles and 18 perches: the whole city is therefore 7 miles and 55 perches in circumference, and, taking in the ſuburbs from Lawrence-hill in the eaſt to the Hotwells in the weſt, is more than 3 miles in length. Its breadth, from Stokes Croft turnpike on the north, to Aſhton turnpike on the ſouth, is upwards of $2\frac{1}{2}$ miles. The number of houſes and inhabitants it is difficult to aſcertain. In the late ſurvey by order of government, the return from Briſtol muſt have been very inaccurate, and is ſtated at 10,896 houſes, and 63,645 inhabitants. Anderſon, in 1758, puts the latter down at 100,000, but gives no documents for this enumeration. The houſes may be ſtated on an average eſtimate at 17,000; and if the environs of Temple-ſtreet, Lewin's mead, College-place, Lime-kiln-lane, &c. be attended to, the rate of 7 to a houſe will not appear too high. This calculation, including thoſe in hoſpitals, alms houſes, &c. will bring it to about 128,000 perſons, which will not far exceed the truth.

Public Buildings, &c. The buildings in the old part of the city are awkward, and the various alterations that have taken place at different periods have deſtroyed all uniformity. The city ſtands on very uneven ground, and very high walls are raiſed round moſt of the houſes; but the enormous height to which they are often built, appears highly unreaſonable, eſpecially when it is conſidered that an encloſing wall has been known to coſt the value of the houſe itſelf. This faſhion is declining, and Briſtol can now boaſt ſome good and handſome houſes, in the open ſtreets, ſquares, &c. Among the principal buildings are the Cathedral, Redcliffe Church, the Exchange, Infirmary, Public Library, Theatre, Aſſembly-rooms, &c.

The *Cathedral* is only part of the original building, which was the church belonging to the abbey of St. Auguſtine, founded by Robert Fitzharding, younger ſon of the king of Denmark, whoſe monument is ſtill preſerved within it. At the diſſolution of the monaſtery, this noble building, then 350 feet in length, was partly demoliſhed; but when the king determined to erect ſix new biſhoprics, of which Briſtol was one, and was informed there was enough of the fabric left for a cathedral, he put a ſtop to its further demolition; the weſtern part being removed, it was left in that mutilated ſtate in which it remains; the preſent fabric conſiſts of the tranſept, the eaſtern part of the nave, and the choir. At the weſt end is a large ſquare tower, highly ornamented and crowned with battlements and four pinnacles. The preſent church, from eaſt to weſt, is 175 feet; its breadth of tranſept, from north to ſouth, 128 feet; the breadth of nave and aiſles 73 feet, and height of the tower 140 feet. The eſtabliſhment is a dean, ſix prebendaries, four minor canons, ſacriſt, &c.; and ſervice is performed twice every day.

The *Church of St. Mary Redcliffe*, ſays Camden, "is like a cathedral, and on all accounts the firſt pariſh church in England." It was founded in 1292 by Simon de Burton, who was ſix times mayor of Briſtol. According to the mayor's calendar, this church was finiſhed A. D. 1376, and was then celebrated for its architecture all over England. The tower and ſpire were 250 feet high; but in 1445 a terrible ſtorm of thunder and lightning deſtroyed part of the ſpire, and the church was much damaged. The latter was repaired by the munificence of Mr. William Cannyngs, merchant, but the ſpire was never rebuilt. The church ſtands on an eminence, called Redcliffe-hill, and is built in the form of a croſs. The nave riſes above the aiſles, is lighted by a ſeries of lofty windows on each ſide, and is ſupported by flying buttreſſes. The tower is large, and with the remain-

ing part of the ſpire, richly ornamented with carved work, and alſo a variety of niches and ſtatues. Though a lofty and maſſy building, yet, from the peculiar beauty of its maſonry, it has a light and airy appearance both without and within. The roof, nearly 60 feet in height, is arched with ſtone, and ornamented with various devices. The church, including our lady's chapel, is in length 239 feet, and the tranſept, from north to ſouth, 117 feet. The breadth of the nave and aiſles is 59 feet, and at the croſs, nave and aiſles, 114 feet. The height of the aiſles both direct and tranſepts is 25 feet. The height of the nave is 54 feet. St. Mary's chapel has been ſeparated from the church, and is uſed as a grammar-ſchool. A peculiarity obſervable in Redcliffe-church is that the tranſept conſiſts of three diviſions, or aiſles, ſimilar to the body of the church, which has a fine effect when the ſpectator places himſelf in the centre of the building, and looks around him. Beſides the above, there are 15 other pariſh churches in Briſtol, ſome of which are modern ſtructures. Temple church is rather curious, and its tower is out of the perpendicular. There are alſo 22 chapels, or places of worſhip for diſſenters of different denominations, and 5 chapels of the eſtabliſhed religion.

The *Exchange*, finiſhed and opened in 1743, was built by Wood, the architect of Bath, at an expence of 50,000 l. It is a handſome building, in the Grecian ſtyle, 110 feet in front, and 148 feet in depth. The principal front is upon a bold ruſticated baſement, the central part of which makes a tetraſtyle of almoſt whole columns, with Corinthian capitals, ſupporting a pediment, in the tympan of which are the arms of England carved in ſtone. The place intended for the merchants is a periſtyle of the Corinthian order, 90 feet by 80, and capable of containing 1440 perſons.

The *General Hoſpital*, for the reception of all caſes, and all perſons of whatever nation, is a handſome edifice, though it has unfortunately never been yet completed.

The *Theatre-royal*, King-ſtreet, is a peculiarly neat and convenient ſtructure: indeed, Mr. Garrick pronounced it to be the completeſt in Europe of its dimenſions; and he wrote a prologue and epilogue, which were delivered at the opening, May 30th, 1766.

The *Briſtol City Library*, is ſo called, becauſe part of its collection belongs to the corporation, and the greateſt part to a ſociety of gentlemen. It contains an excellent aſſemblage of ancient and modern books, which, by donations and annual ſubſcriptions, are rapidly increaſing. They are contained in a large freeſtone building erected for the purpoſe, with a convenient houſe for the head librarian, who has alſo an aſſiſtant librarian.

The *Aſſembly-room*, in Prince's-ſtreet, has a beautiful front of free-ſtone, conſiſting of a ruſtic baſement, with a central projection ſupporting four Corinthian columns, coupled and crowned with an open pediment. On the frieze, in relievo, is the following motto: "Curas cithara tollit," Muſic diſpels care.

To theſe may be added, the *Guildhall*, where the aſſizes, ſeſſions, and other public buſineſs are tranſacted.

Government, civil Officers, &c.—The original government of Briſtol ſeems to have been mixed, military and civil; the chief authority reſiding in the lord conſtable of the caſtle, who deputed another officer for the execution of juſtice, called "prepoſitus villæ," or provoſt of the town. The earlieſt account of this officer occurs in Domeſday-book. In the reign of king John, Briſtol obtained a charter to be governed, like London, by a mayor, &c. From the Annals, it appears, that the civil government, at different periods, has been variouſly modelled, as appears from the following liſt:

1.	Till A. D. 1205.	A prepoſitor under the cuſtos of the caſtle.
2.	1266.	A mayor and two prepoſitors.
3.	1313.	A mayor and two ſeneſchals.
4.	1372.	A mayor and two bailiffs.
5.	1500.	A mayor, ſheriff, and two bailiffs.
6.	To this day.	A mayor and two ſheriffs choſen annually.

The government of the city is now adminiſtered by a mayor, a recorder, twelve aldermen, who are all juſtices of the peace, two ſheriffs, an under-ſheriff, twenty-eight common-council-men, town-clerk, deputy town-clerk, chamberlain, vice-chamberlain, ſteward of the ſheriffs' court, clerk of the arraigns, regiſtrar of the court of conſcience, and alſo a high ſteward. There are other officers pertaining to the corporation, as ſword-bearers, two coroners, water-bailiff, quay-maſters, ſchool-maſters, clerk of the markets, keepers of the priſons, inſpectors of nuiſances, eight ſerjeants at mace, criers of the court, common-crier, exchange-keeper, ſheriffs' officers, club-men, city marſhal, and a band of muſicians in conſtant pay. Great form is obſerved on the 15th of September, in the election of mayor, when the whole body corporate is convened. He is allowed 1000l. for the year of his mayoralty, and the ſheriffs 500l. each for the year of their ſhrievalty. The mayor has the higheſt marks of honour granted to magiſtracy, ſcarlet ermine gowns, ſword, mace, cap of maintenance, &c. He holds a daily ſeſſions in the council-houſe to hear complaints, and accommodate differences, courts of conſcience, and pie-powder, quarterly ſeſſions, and a general jail delivery twice a year: one for the deciſion of civil, and the other of criminal cauſes, wherein the court has the power of life and death. The mayor, aldermen, and common council have the cuſtody of the city ſeal, which is impreſſed with the city arms. Theſe are gules, a caſtle on a hill by the ſea-ſide, and the helm of a ſhip paſſing by, all proper; to which were afterwards added two unicorns as ſupporters. The motto is, "Virtute et Induſtriâ."

From the time Briſtol was made a county of itſelf, it has, by various charters, and grants, been endowed with additional privileges and immunities, all of which were confirmed by a new charter from queen Anne. By another of king Edward IV. 1461, Briſtol was exempted from the authority of the high admiral of England by land and water; and the right of determining differences, belonging to the court of admiralty, was referred to the mayor and corporation. The juriſdiction by water extended up the river only to lower Harrate, till an act of William carried it to Hanham; thence it reaches to Kingroad and down the channel to the Flat-holmes. To this place, Gildas, the ancient Britiſh ſaint and hiſtorian, retired, and here he died. The opulent corporation of Briſtol is poſſeſſed of large eſtates, both in the city and in the country; and they are the patrons of ſeveral church livings, ſo that they not only poſſeſs great influence, but have it in their power to encourage genius, and reward induſtry and merit. The city is divided into twelve wards, each of which has an alderman to preſide over it. The recorder is always one of the aldermen, and, by virtue of his office, the principal. The ſenior alderman, as in London, is called the father of the city. Every ward has one chief conſtable, and twelve others, a night conſtable, and a proper number of watchmen under him.

Briſtol contains three priſons: Newgate, at the end of Wine-ſtreet, which is a gaol for malefactors and debtors; Bridewell, or the city priſon, for the confinement and correction of leſs offenders; and at the end of Glouceſter-ſtreet is a priſon, on Howard's plan, for that part of the ſuburbs

which ftands in the county of Gloucefter, and a Bridewell on the Somerfet fide. The act for lighting Briftol with lamps was procured in the reign of William III. This obliged the citizens to hang out their own lamps; but they are now provided, and the lighting contracted for, by the different parifhes. Moft of the ftreets are well paved on the fides with flag ftones; but the pitching with pebbles in the carriage-way is at prefent extremely uneven and bad, and requires amendment. The poor rates are feparately affeffed, and collected on the refpective parifhes; but the poor are taken care of conjointly, and have a houfe called St. Peter's hofpital. There are fourteen ftands of hackney coaches in various parts of the city, and one at Dowry fquare. Each coach is numbered, and marked C. B. There has lately been inftituted at Briftol a fociety for the fuppreffion of vice.

Briftol appears to have been a *borough* at the Conqueft, and at a very early period, by ancient prefcription, fent two burgeffes to parliament. A lift of its reprefentatives is ftill extant from the 23d of Edward I. 1295. None can vote for members but fuch as are free of the city, which freedom is attained by fervitude, by hereditary right, by marrying a freeman's daughter, or by purchafe. The number of freemen, at prefent, is about 8000. The city gives title to an earl, and the earldom was formerly in the noble family of Digby, but is now in that of Hervey.

Commerce, Trade, Shipping, &c.—That a port fo fituated as Briftol fhould have early participated in the commerce of the country, can be no matter of furprize. William of Malmfbury, in 1139, fays, it was a place much addicted to trade, and was then full of fhips from Ireland, Norway, and every part of Europe, which brought hither much commerce, and great foreign wealth. From the charter of king John fomething may be learnt of the commerce of the place in his reign, but more will be furnifhed by that of Edward III. Briftol was grown fo opulent in 1327, that the mayor and commonalty lent the king (Richard II.) 500 marks, which is the firft inftance (except London) in the Fœdera of a lay community lending money to the crown; and, in future loans, we find Briftol follow London. In 1487, a petition was prefented to the king, to empower the citizens of Briftol to remove all obftructions in the river Avon that impeded its navigation between Briftol and Bath; for before the time of Richard I, the Avon was navigable to Bath. In 1711, an act of parliament was obtained, at an expence of 15,000l. to amend this navigation by placing wears, locks, and other obftructions. In the roll of the fleet of Edward III. which was at the fiege of Calais, in 1347, we find the proportion of fhips and men furnifhed, on that occafion, by London and Briftol: the former fupplied 25 fhips, and 662 men, and the latter quota was 22 fhips, and 608 men. William Cannyngs is diftinguifhed as a great merchant here in 1449, and he appears to have traded with peculiar privileges, to Pruffia, the Hanfeatic towns, and Denmark. William of Worcefter fays, that Cannyngs employed for eight years, in his own fhipping concerns, 800 men, and he fpecifies the fhips and tonnage employed by him. The fame Cannyngs paid king Edward IV. 4000 marks for his peace, *i. e.* for leave to trade to prohibited places, and to be free of impofts and duty.

The commercial character of the Briftol merchants will beft appear from the letters patent which were granted to John Cabot, a Genoefe by birth, but a refident merchant in this city, and to his three fons, who fitted out veffels for the purpofe of difcovery. In 1527, Robert Thorn obtained leave to go on a voyage of difcovery, to find out a north-weft paffage. In 1583, fir Humphrey Gilbert performed a voyage for the colonization of America, an account of which is given in Hackluyt. Many other voyages were afterwards made from Briftol, with the like public-fpirited views, though not with equal fuccefs. The merchants had, previous to 1526, traded to St. Lucar in Spain, and thence to the Canaries, fending out cloth, foap, &c. and bringing in return fugar, drugs, dye-ftuff, &c.; and De Wit, in his intereft of Holland, fays, this city very early engaged in the cod-fifhery on the coaft of Newfoundland, and alfo entered into the Weft India trade foon after the difcoveries were made. In 1556, the merchants were incorporated into the fociety called Merchant Venturers: and various grants, immunities, and franchifes, were annexed to their fociety. Sebaftian Cabot was conftituted the firft governor. In 1588, four fhips were fitted out from Briftol to join the Queen's fleet at Plymouth. With regard to the prefent ftate of trade, it is very confiderable to Florida, Carolina, Virginia, New York, Newfoundland, Quebec, Spain, Portugal, Weft Indies, Denmark, Sweden, Ruffia, Pruffia, &c. The ardour for the African trade feems much to be abated; and the Briftolians now yield the palm of traffic in human beings to the rival port of Liverpool. The merchants in Briftol trade with a more entire independence on London than any other port in Britain. Whatever exportations they make to any part of the world, they can import the full returns, and find a market, without configning their fhips or cargoes to London. They have buyers at home for their largeft importations, confequently the fhopkeepers of Briftol, moft of whom are wholefale dealers, keep up a great inland trade, having riders and carriers, like the London merchants.

The quay of Briftol, which was commenced where the bed of the Frome was altered, reaches round from the ftone bridge on the Frome, to the new handfome bridge over the Avon; in extent one mile, being one uninterrupted wharf of hewn ftone, with fufficient depth of water, at flood tides, for the largeft fhips to ride clofe to the walls, and difcharge their cargoes. Thefe, as the tide ebbs, ride fafe at their moorings on a foft oozy bed of mud; but foreign and fharp keeled fhips are often ftrained, and obliged to go into dock after lying here. This occafioned a new floating-dock to be made, at the expence of 20,000l. It is fituated near the Hot-well-road; its gates will admit a 64 gun veffel, and it will contain 40 fail of fhipping. Here alfo are dry and wet docks, for repairing and building fhips. A fcheme has long been in contemplation to dam up the water, and keep the veffels in the harbour conftantly afloat. In 1803, an act of Parliament was obtained for the purpofe, a plan was adopted, and this great work is now executing with all poffible expedition. When completed, the port will be capable of holding 1000 fail of fhipping, which convenience muft, eventually, be of great advantage to the city. The plan is to dam up to a certain height the whole of the prefent bed of the Avon and Frome, and to make a new channel for the river through Redcliffe meads. Three hundred thoufand pounds are already fubfcribed, and three years given to accomplifh the defign. From what has already been done, it is conjectured that the expenditure will not exceed the eftimate; and if workmen can be obtained, it is prefumed that it will be finifhed within the affigned period. By this plan, fhips will not only be kept afloat at the quays, but may enter the locks, and go to fea at neap tides, which will be a wonderful faving in time and expence; and a navigation will be opened up the Avon, as high as the town of Keynfham, in one level: the money to be raifed by duties and taxes, bearing an intereft of 4 per cent. and not exceeding 8 per cent The intereft is to be raifed by a tax on houfes in the city, of

one shilling per pound rent, and a port-duty on all goods and merchandize imported. The tax on houses is considered too partial to be just; and the duties on articles imported may probably act as a considerable prohibition on foreign vessels frequenting the port. Time alone, however, must discover the policy or impolicy of thus raising the sum necessary for its accomplishment. The trade of this port has been ever fluctuating from the time of Henry II. 1137, (when William of Malmsbury makes such honourable mention of it) to the present time. Every vessel of above 60 tons burthen pays a certain wharfage; and from the water-bailiffs' returns, it appears that, in 1745, it amounted to 918l. 18s. 7½d: in 1775, to upwards of 2000l. In 1742, the privateers fitted out from Bristol, according to Barret, exceeded in tonnage, number of guns and men, the whole royal navy of Great Britain. In 1769, there were entered inward at the Custom-house 427 foreign ships, exclusive of Londoners, Coasters, &c.

In 1787 the entry at the custom house was as follows:

		Ships	Tons.		Ships.	Tons.
Entered inwards—	Brit.	416	48,125	Foreign,	69	11,112
Entered outwards—	Brit.	382	46,729	Foreign,	66	10,445

The following is a list of ships and vessels belonging to this port in 1787:

Foreign Trade.			Coasters.			Fishing Vessels, &c		
Ships	Tons	Men.	Ships.	[illegible]	Men.	Ships.	Tons.	Men.
328	53,491	3971	30	3078	142	7	340	30

After this period the trade increased considerably; and another computation states, that in 1788, 34 ships were employed to Jamaica, 38 to the Leeward islands, 37 to Africa, 33 to Newfoundland, 50 to North America, and 200 between Bristol, Ireland, France, Spain, London, &c. amounting to 1392; besides 103 trows from 50 to 130 tons burthen, employed in the Severn and Wye trade. But the commerce of Bristol received a severe check during the last war; and the present paralizes the spirit of adventure, and the hand of industry. Should peace quickly return, and the port be finished, there can be little doubt but this place will become more flourishing than ever.

Besides the foreign trade, Bristol has many very considerable manufactures; and the cheapness of fuel, with the ready conveyance to a market, renders this an advantageous place for carrying on various trades. The brass rollery business was begun here about 1704. The manufactory of zinc out of calamine stone, and the ore of zinc called black Jack, was established at Bristol in 1743, for which Mr. Champion obtained a patent. Mr. Emerson at Hanham established works for making brass, by exposing copper to the fumes of calamine, and obtained the finest brass in the world. Vide Watson's Chemistry.

The glass houses of Bristol are not only numerous, but great quantities of different glass articles, and bottles, are annually made here. This trade is increasing, and it is said that more glass is manufactured at Bristol than at any other place in England. Many large iron founderies are also established here, and a steam-engine factory is erected for boring cannon; smelting lead, and making of white and red lead, are among the manufactories of this city.

There are 20 sugar-houses for the refining and manufacture of sugars; several large distilleries, which help to supply London; and the exportation to foreign parts is very considerable. The manufacture of soap has long been an article of great trade here; for, in 1523, it supplied London with the best gray speckled soap at 1d. per pound; but it is now 1s. Large quantities are still sent to London, to most parts of the kingdom, and to America. This place was, at an early period, noted for its woollen trade. In 1339, we find from Rymer, that the cloth manufacture was removed from Flanders, when Bristol was appointed a principal staple of wool, and many looms were set up for weaving woollen cloths. In Henry VIIIth's reign, it was full of clothiers, weavers, and tuckers; and the magistrates gave great encouragement to set up the Colchester rug manufactory, and many sums have at times been left to the corporation in trust for the use of young clothiers. This trade is not entirely taken away, as some woollen stuffs, serges, &c. are still made. The manufacture of silk fringes, sail cloth, cottons, morocco-leather, &c. must not be omitted. Several potteries also now rival those of Staffordshire.

Military History, Castle, &c.—It is highly probable, that so conspicuous and important a place early partook of the disasters arising from the internal commotions of this kingdom, and the evils arising from foreign invasion. But history is silent, the records being lost till 915, when Stow says, a great navy of Danes sailed up channel and infested the western coasts, landed in divers places, and took great plunder; at which time Bristol suffered from the marauding enemy. King Edward son of Alfred, 911, according to the Saxon annals, sent his army out of Mercia, and met them in Wessex, where he fought and routed them. The battle was decisive, and the Danes were then subject to the Saxon monarch. Edward went on to build towns and castles; and amongst others he built that of Bristol, on the Mercian side of the river Avon. Camden, therefore, was evidently mistaken when he asserts that Robert Rufus, natural son of Henry I. was the founder of the castle of Bristol. Turgot mentions it as the work of Edward in 915, and says, it was "the goodliest of five built on the banks of Avon;" and in 1088, it is mentioned by Roger Hoveden as "Castram fortissimam:" and if it were so strong 20 years after the conquest, there cannot be a doubt, but it previously existed as a fortress for the defence of the city. Another decisive proof of Camden's error is, that the castle was held by Godfrey bishop of Constance, and Robert de Mowbray earl of Northumberland, in a rebellion against king William Rufus in 1088; before king Henry I. earl Robert's father, was at man's estate. This earl, though not the founder, certainly rebuilt some parts, repaired others, and erected a palace and other offices. He also built a magnificent tower, scarcely equalled at that time in England, and encompassed the whole with strong walls. Leland informs us, that Robert built part of it, and that "the dungeon tower was made of stone brought out of Normandie by the redde earl of Gloucester." It was not till 1130, that earl Robert began to rebuild and improve the castle; which, excluding the out-works, was 450 feet from east to west, and 300 feet from north to south. There were in it two great courts, many towers, a church, and a magnificent chapel. The king had also a palace within the walls. The principal buildings stood upon an area, covering 3¾ acres of ground, exclusive of courts, yards, and other accommodations for the officers and the garrison. Leland informs us, that the great tower stood in the north west part of the castle; and in his time, about 26th of Henry VIII., the whole was in a decayed state, and tending fast to ruin. In the reign of John, the castle was annexed to the crown; and here that monarch cruelly confined the princess Elcanor, (called the damsel of Brittany,) who, after forty years miserable confinement, died here in 1241. In the barons wars, during the reign of Henry III., prince Edward his son supplied the castle with provisions, and fined the

townsmen 1000l. for not affifting him with fupplies. The latter befieged him in the caftle, and the prince fled to Windfor, where he was foon forced to accept terms at the hands of the barons. When the duke of Lancafter oppofed Richard II. the inhabitants of Briftol threw open their gates to the duke's forces, who ftormed and took the caftle, in which many of the king's friends had taken refuge. The inhabitants of Briftol fided with the earl of Richmond, afterwards Henry VII. at which time Giles lord d'Aubeney held the caftle. During the reformation, tumults broke out in the weft; and at Briftol, the caftle walls, and gates of the city were repaired and mounted with cannon; but by the prudent conduct of Mr. William Chefter, the difcontents were foon appeafed, and a general pardon was procured for the delinquents. In the years 1545 and 1553, a mint was eftablifhed in the caftle; and the church plate, feized by the commiffioners, was here coined. By a petition to king Charles I., 1629, the king granted the caftle and its appurtenances to the mayor and corporation of Briftol, and made it a part of that county and city; and in 1631, it was fold to the mayor and burgeffes for 959l. In the commencement of the war, between the king and his parliament, the caftle was repaired and garrifoned by the parliament-army under the government of Col. Nath. Fiennes. This was confidered a place of the greateft confequence, and ferved to awe all the weftern counties, having accommodations for a large army. The king, therefore was very defirous of obtaining poffeffion; a plot was formed by Yeamans and Bouchier, to deliver it up to the king's forces; but this being difcovered, prince Rupert, at the head of a confiderable army, befieged it; but fearing the length of a blockade, he determined to take it by ftorm, which he quickly effected. But the place was thus dearly bought, for the king loft moft of his valuable officers, and more than 500 of his beft troops. It was thought of fo much confequence, that a public thankfgiving was ordered for the fuccefs of his majefty's arms. The citizens fubfcribed 1400l. to prevent the plunder of the foldiery; and orders were confequently given for death to be the penalty of plunder. Briftol was ordered to pay 50,000l. in money, and clothe and equip 1500 of the king's foldiers. At the battle of Nafeby, prince Rupert repaired to Briftol, which he found fupplied with men, provifions, and ammunition, fo that he wrote to the king, affuring him he was able to fuftain a four months' fiege. This revived the hopes of the king's party; and it was thought that the prince would make a vigorous and defperate defence; but, to the furprife of all, he made but a very feeble and fhort refiftance.

This unexpected and difaftrous event damped the royal caufe, which from that day rapidly declined; and certainly the capitulation of this grand ftation haftened the fatal cataftrophe of the king's fubmiffion, and fubfequent decapitation. After Oliver Cromwell was proclaimed protector, he iffued orders for the demolition of the caftle of Briftol. The difmantling was begun in 1665, and the whole was razed to the ground. Scarcely any veftiges are now remaining. Thus this fortrefs, deemed impregnable in former ages, and which has made fuch a diftinguifhed figure on the page of hiftory, the fubject of fo much negotiation, and fo much contention, was deftroyed after having weathered the ftorms of feven centuries. The inhabitants, previous to this period, appear to have always been in oppofition to the reigning princes, but fubfequently, however, the reverfe appears the cafe. In the duke of Monmouth's rebellion, they efpoufed the caufe of king James. During the rebellion, in the reign of George I., and efpecially in 1745, they were decidedly for the houfe of Hanover; and in the prefent day their exertions in defence of the nation are too well known to need a comment.

Such are the moft material places, objects and events, connected with the city of Briftol. We may further ftate that its buildings cover an area of about 1000 acres of ground, and the fuburbs above 500 more. With the appendages it contains 600 ftreets, fquares, lanes, courts, &c. in which are erected 47 churches and chapels. Here are 5 hotels, 50 inns and taverns, 7 banking houfes, and 4 prifons. It is the chief city, quay, and mart of the weftern parts of the kingdom, and is claffed among the principal cities of Europe.

Briftol is the birth-place of many diftinguifhed literary and public characters, the memoirs of whom will be introduced under their refpective heads. We fhall therefore only mention the names of the principal: Thomas Chatterton, poet, fir William Draper, William of Worcefter, William Cannyngs, Edward Colfton, Ann Yearfley, Mary Robertfon. For an account of the Hotwells, Clifton, St. Vincent's rocks, and many places in the vicinity, fee CLIFTON. Barret's Hiftory of Briftol, 4to. 1789.

Britain

BRITAIN, Great, the most considerable island of Europe, comprehending the two kingdoms of England and Scotland, with the principality of Wales, and extending from Lizard point, N. lat. 50° nearly to Dungsby-head in N. lat. 58° 30′ nearly. Accordingly, its length is about 590 miles. Its greatest breadth from the Land's End, in W. long. 5° 45′. to the North Foreland, in E. long. 1° 17′. is about 488 miles. Its form, however, is somewhat triangular; as it has three promontories, projecting in different directions, viz. the Land's End, in Cornwall, towards the west; the North Foreland, in Kent, towards the east; and Dungsby-head, in Caithness, towards the north; and the circuit of its three sides, allowing for the windings of the coast, contains, by a general estimate, about 1800 miles. But if Great Britain were considered as a perfect triangle, the length of its three sides would measure about 1520 British miles. It is bounded on the north by the Northern Ocean, on the west by the Atlantic and the Irish Sea, which separates it from Ireland, on the south by the British Channel, which divides it from France, and on the east, towards Germany, by the North Sea and German Ocean. Some have supposed, that Great Britain was, in times of very remote antiquity, united with the continent. The entire separation of Great Britain from the continent must have happened, according to the conjectures of Mr. Kirwan, (Irish Transact. vol. vi. p. 301.) long after the deluge, and that of Ireland from Great Britain at a still later period; for wolves and bears were anciently found in both, and these must have passed from the continent into Britain, and hence into Ireland, as their importation cannot be suspected. The divulsive force that separated Britain from Germany seems, according to this writer, to have been directed from north to south, but gradually weakened in its progress. Hence that island is sharpened to the northward; but the impression must have been considerably enfeebled by the opposition of the granitic mountains that form the Shetland and Orkney isles. The broken structure of the calcareous or argillaceous and arenaceous materials of the more southern parts presented less resistance, were more easily preyed upon, and gave way to what is now called the German Ocean, while these materials themselves were spread over Westphalia, &c. or formed the subsoil of Flanders, Holland, and the sand-banks on its coast. The rupture of the isthmus that joined Calais and Dover was probably effected by an earthquake at a later period, and gradually widened by tides and currents. Ireland was protected by Scotland from the violence of the northern shock; and hence its separation from Scotland appears to have been late and gradual. That from England was probably diluvial, and effected by a southern shock. These changes, says this writer, happened at least 3600 years ago. But to return from this digression.

The fertility and pleasantness of Great Britain gave occasion to imagine that these were the fortunate islands, described by the poets, where the face of nature exhibited a perpetual spring. In former times this was the granary of the western empire: from hence was transported every year an immense quantity of corn for the supply of the army on the frontiers of Germany. As to the history of its more early state, its population, fertility, and a variety of other circumstances relating to it, we refer to the next article.

The climate of Great Britain is, perhaps, more variable than that of any other country on the globe; and this circumstance has been ascribed to the opposition between the vapours of the Atlantic Ocean, and the drying winds from the eastern continent. The western coasts are subject to frequent rains; and the eastern part of Scotland has a clearer and drier temperature than that of England. The humidity of the climate, whilst it invests the delicious vales and meadows with a verdure unknown to any other region, injures the health of the inhabitants, by occasioning colds and catarrhs, which too frequently terminate in consumptions, that are fatal to many in the prime of youth. Besides, the moist and foggy climate conspires, with the excessive use of gross animal food, to produce that melancholy, which foreigners have considered as a national characteristic of the country. To the mutability of the climate we may reasonably ascribe the precariousness of the seasons. To this purpose it has been observed by some judicious persons, that since the year 1775, a considerable change has taken place, with regard to the temperature of the year, both in Great Britain and Ireland. The winters have been, in general, more moist and mild, and the summers have been more humid and more cold, than the average of preceding years. With us the year might not improperly be divided into eight months of winter and four of summer. The spring dawns in April, which is commonly a mild month, but eastern winds prevail in May, and check the efforts of reviving nature, and disappoint the promise of the year. June, July, August, and September, are usually warm summer months, with occasional frosty nights even in August, and cold east wind; and some summers have of late years been chilled by constant rain. Our winter commences with the beginning of October, which, however, is often a mild and pleasant month; severe frost does not commonly occur till Christmas. November is the most gloomy month of the year; and allowed, generally, to be the most unsettled month, interspersed with dry frost, cold rains, and strong winds, with storms of hail and sleet. But all observations of this kind must be considered as general in their nature; and counteracted by different situations with regard to latitude, and by a variety of local circumstances.

The population of Great Britain has been variously estimated; some reckoning it at 7,000,000, and others at more than 12,000-000. But in the year 1800 an act was passed, (41 Geo. III.) "for taking an account of the population of Great Britain, and of the increase or diminution thereof." From an abstract of the returns made to parliament, in consequence of this act, the following result was deduced:

SUMMARY of ENUMERATION.

	HOUSES.			PERSONS.		
	Inhabited.	By how many families occupied.	Uninhabited.	Males.	Females.	Total.
England - - - - -	1,472,870	1,787,520	53,965	3,987,935	4,343,499	8,331,434
Wales - - - - -	108,053	118,303	3,511	257,178	284,368	541,546
Scotland - - - - -	294,553	364,079	9,537	734,581	864,487	1,599,068
Army, including militia - -	- - -	- - -	- - -	198,351	- - -	198,351
Navy, including marines -	- - -	- - -	- - -	126,279	- - -	126,279
Seamen, in registered shipping	- - -	- - -	- - -	144,558	- - -	144,558
Convicts, on board the hulks -	- - -	- - -	- - -	1,410	- - -	1,410
Totals -	1,875,476	2,269,902	67,013	5,450,292	5,492,354	10,942,646

On this enumeration it is observed, that the total population of Great Britain probably exceeds the number of persons specified in the above summary, in as much as from some parishes no returns were received. From the number of houses in Ireland, nearly ascertained by the collection of a hearth-money tax, it has been computed, that the population of that part of the united kingdom somewhat exceeds four millions of persons. It should also be observed, that the islands of Guernsey, Jersey, Alderney, and Sark, the Scilly islands, and the Isle of Man, were not comprised in this enumeration; and that the total population of these islands has been usually estimated at about 80,000 persons. On these considerations, with a very moderate allowance for omissions in the returns, the total population of the united kingdom of Great Britain and Ireland amounts to *fifteen millions one hundred thousand* persons; and besides these, its eastern and western possessions and colonies contain many natives of the British isles. On a more enlarged survey of these colonies and settlements, we may consider their inhabitants either as subjects of Great Britain, or as augmenting its importance by their intimate connection with it. The most important of these are now in Asia; and in Hindostan, the nations subject to Great Britain cannot be now calculated at less than 40 millions. The acquisition of the Dutch settlements, the colony of New Holland, and more minute stations, must also be taken into the account. In America, and what is called the West Indies, Canada, Nova Scotia, Newfoundland, and the more northern settlements, with Jamaica, and the other islands, may, perhaps, contain a million. In Africa, the settlements at the Cape of Good Hope, the islands of St. Helena and at Sierra Leone, present an insignificant number; and Gibraltar is to be regarded merely as a military station. However, if we compute the North American states, detached from the mother country, at a population of five millions, the united kingdom of Great Britain and Ireland at 15 millions, and our colonies and settlements at only two millions, we shall find in the various countries of the globe an increasing population of 22 millions, diffusing the English language and manners to a vast extent, and contributing in one way or other to the wealth, power, greatness, and prosperity of Great Britain.

From the above table it appears, that the enumeration of 1801 amounts to 8,872,980 persons for England and Wales; and to this number an appropriate share of soldiers and mariners is to be added. These appear to have been 469,188; and if, exclusive of them, the total population of the British isles is 14,630,812, (15,100,000—469,188) about a thirtieth part may be added to the inhabitants in order to ascertain the population of any distinct part. Accordingly, in the following table, the existing population of England and Wales is taken at 9,168,000; and the population attributed to the other years, is obtained by the rule of proportion, thus: if 255,426 baptisms (the average medium of the last five years, deduced from the returns of parish registers,) were produced from a population of 9,168,000, from what population were 152,540 (the baptisms of 1700, given in the same returns) produced?

TABLE of Population throughout the last Century.

ENGLAND and WALES.	
In the Year.	Population.
1700 - - -	5,475,000
1710 - - -	5,240,000
1720 - - -	5,565,000
1730 - - -	5,796,000
1740 - - -	6,064,000
1750 - - -	6,467,000
1760 - - -	6,736,000
1770 - - -	7,428,000
1780 - - -	7,953,000
1785 - - -	8,016,000
1790 - - -	8,675,000
1795 - - -	9,055,000
1801 - - -	9,168,000

Upon a view of this table it may be observed, that although the beginning of the century exhibits a decreasing population, the lost number had been regained in 1720; and since that time a continual, though irregular, increase is manifest. It also appears, that the population of England and Wales, in 1801, compared with that of the beginning of the last century, is as 1,000 to 597, or nearly as ten to six.

The following table for Scotland is formed in the same manner; but being founded on a collection of no more than 99 parish registers, from different parts of the country, it is of much less authority. These parishes contain less than a seventh of the whole population. In Scotland there are in all about 900 parishes.

TABLE of Population throughout the last Century.

SCOTLAND.	
In the Year	Population.
1700 - - -	1,048,000
1710 - - -	1,270,000
1720 - - -	1,390,000
1730 - - -	1,309,000
1740 - - -	1,222,000
1750 - - -	1,403,000
1760 - - -	1,363,000
1770 - - -	1,434,000
1780 - - -	1,458,000
1785 - - -	1,475,000
1790 - - -	1,567,000
1795 - - -	1,669,000
1801 - - -	1,652,370

The population of Scotland, in 1801, compared with that of the beginning of the last century, appears to be as 1000 to 634, or nearly as 10 to 6½, which, as the 99 parish registers were received from the manufacturing parts of Scotland, gives too high a statement of the increase of population.

In the year 1695 a poll-tax was levied in Ireland; and on this occasion it was calculated, that the number of inhabitants was 1,034,000; but the usual evasion of taxation may be supposed to have considerably lessened the real number. About the year 1795, Ireland contained, at least, 4,000,000, and since that time the number has not increased. However, it may not be very erroneous to estimate the population of Ireland at 1,500,000 in the year 1700, and at 4,000,000 in the year 1801. If this be granted, the population belonging to all the British isles has increased during the last century from 8,100,000 to 15,100,000.

Of the population of Great Britain, the army has, of late years, engrossed a considerable share. It consists of regulars, in cavalry, and infantry, and the militia, exclusive of artillery and engineers. The volunteer corps in Great Britain and Ireland amounted in December, 1803, to 430,000; and on the 1st of January, 1805, the secretary of war made the following return of the state of the British forces at home, and on foreign stations, viz. 21,223 of cavalry, including 1,088 horse artillery; 8,559 of artillery; 124,878 of infantry, including 20,747 men for limited service, and 21,208 men belonging to foreign and provincial corps in British pay; and 89,809 of militia: so that the whole British force, in regulars, militia, and volunteers, amounts to 674,469 men. To these we may add the royal regiment of artillery, the horse brigade, the brigade of gunners and drivers, and companies of foreign artillery, amounting on the 1st of January, 1805, to 16,670; and the corps of royal artillery, artificers and labourers, including, at the same period, 704 men.

But the great rampart and supreme glory of Great Britain consist in her navy, in size, strength, and number of ships, far exceeding any example on record. In 1805, the total of ships in commission amounted to 684, consisting of 111 of the line, 19 fifties to forty-fours, 150 frigates, and 404 ships of various kinds; besides several repairing, in ordinary, and building: amounting in the whole to 895. For this immense fleet, the number of seamen, annually voted, amounts from a hundred to a hundred and twenty thousand; a number which no other country ancient or modern could have supplied. To support the expenditure occasioned by the army and navy of Great Britain, to defray the other charges of government, and also to discharge the interest of the national debt, a very large sum is raised by a variety of taxes, in aid of the revenue, arising from the excise and customs. The ability of the country for bearing the burden which its exigencies impose upon it, consists in the produce of its land and manufactures, and in the circulation of property, occasioned by its domestic trade and foreign commerce. These sources of national wealth have been improved to an astonishing degree in the course of the last century and a half. Availing ourselves of the estimate of the national wealth of Great Britain, furnished by Mr. Grellier, an ingenious writer, in one of our periodical publications (Monthly Magazine, vol. x.) we shall subjoin the following statement of its vast increase during the period above mentioned. In 1664, sir William Petty estimated the wealth of England at the sum of two hundred and fifty millions. His computation is subjoined.

Value of the land; being 24 millions of acres, yielding 8 millions per annum rent, worth at 18 years purchase -	£.144,000,000
Houses; reckoning those within the bills of mortality, equal in value to one-third of the whole - - -	30,000,000
Shipping; 500,000 tons, at 6*l.* per ton, including rigging, ordnance, &c. -	3,000,000
Stock of cattle on the 24 millions of acres and the waste belonging to them, including parks, fisheries, warrens, &c.	36,000,000
Gold and silver coin, scarce - -	6,000,000
Wares, merchandize, plate, furniture -	31,000,000
	£.250,000,000

But since the time when this computation was made, a great difference in the value of money has taken place, which difference appears from the table of sir George Shuckburgh Evelyn, in the Philos. Trans. for 1798, part 1, page 177, to be in the proportion of about 5 to 14; and, therefore, the total wealth of England and Wales, in 1664, would have amounted to 700,000,000*l.* according to the present value of money.

The value of land has progressively increased, in consequence of improvements in cultivation, and the increased consumption of its produce, from 18 years' purchase, at which sir William Petty states it, to from 28 to 30 years' purchase. The whole landed rental of England and Wales, and the Low-lands of Scotland, was stated by this writer at about 9 millions; and if he had included the High-lands of Scotland, it is reasonable to suppose that he would not have made the whole rental of the island more than 9,500,000*l.* G. King and Dr. Davenant, in the reign of queen Anne, stated the rental of England and Wales at 14,000,000*l.*: about 25 years ago, it was generally reckoned at 20,000,000*l.*: but at present it considerably exceeds that sum. The cultivated land appears, from the statement of Mr. Middleton, in his "View of the Agriculture of the County of Middlesex," to be 39,027,000 acres, and the commons and waste-lands to be 7,889,000 acres; and, therefore, the total of acres in England and Wales amounts to 46,916,000 acres. If, therefore, we consider the commons and waste lands as equal in annual value to only one million of cultivated acres, the whole may be taken at 40 millions: and taking the average rent, which, at 15*s.* per acre, appears to be a moderate computation, at a tenth less, the rental amounts to 27,000,000*l.* and the value at 28 years' purchase to 756,000,000*l.* The number of cultivated acres in Scotland is upwards of 12 millions, and of uncultivated acres upwards of 14 millions, which, being of little use, may be wholly excluded; and the cultivated part, being rated at an average of 10*s.* per acre, yields the sum of 6,000,000*l.*

per annum: and the total rental of Great Britain will be 33,000,000l. and the value of the land, at 30 years' purchase, be 990,000 000l. Other writers have endeavoured to prove, (see Beche's "Observations on the Produce of the Income Tax,") that in the whole extent of England and Wales there are no more than 38,500,000 acres of land; and that Scotland, with its adjacent islands, contains about 21 million of acres. It is not so easy to ascertain the value of the houses as it is to determine the value of the land; but the following statement of their rent, founded on the numbers returned as chargeable and excused to the window duties, in England and Wales, in 1781, will not be thought too high:

	Rent.
Number of cottages 284,459, at 20s. per annum - - - -	£ 284,459
Number of houses under 10 windows, 497,801, at 5l. per annum - -	2,489,005
Number of houses under 21 windows, 171,177, at 15l. per annum - -	2,567,655
Number of houses, above 20 windows, 52,373, at 40l. per annum - -	2,094,920
Total -	£ 7,436,039

The total rent, at 20 years' purchase, makes 148,720,780l. and including Scotland at less than a sixth of England and Wales, the whole will amount to 170,000,000l.

In order to form an idea of the value of cattle and farming stock, on the land, we may consider the black cattle and calves, sheep and lambs, swine, pigs, and poultry, annually consumed in London as worth 6 000,000l. which cannot be more than a seventh part of the whole consumption, amounting therefore in value to 42,000,000l.: but the whole number of cattle existing must be more than double the quantity brought to market; so that, including horses, asses, cows kept for milk, and oxen employed in agriculture, the whole value of the cattle cannot be less than 90,000,000l.

Taking the annual consumption of grain of all sorts at 14,000,000 quarters, which is probably below the truth, it may be presumed, that in general there is at least three or four months' supply on hand, which, at only 35s. per quarter, will amount to at least 6,125,000l. The value of hay and straw, and all kinds of fodder and of all implements of husbandry, cannot be less than five or six millions, and with the former sum will make about 12,000,000l. The total value of cattle and farming stock is therefore 102,000,000l.; and if it be estimated as equal in value to only three times the yearly rent, it will amount to nearly this sum.

The value of the shipping belonging to Great Britain may be more accurately ascertained: for it appears that, in 1794, the tonnage of the vessels in the merchants' service was 1,589,162 tons; but taking it at 1.500,000l. at 8l. per ton, it makes 12,000,000l. and this is without doubt below the real value. In the year ending the 5th of January, 1804, the number of British ships entered inwards was 11,396; their tonnage 1,614,365; and the number of foreign ships 4,252, and their tonnage 638,034; the number of British ships cleared outwards, was 3,662, and their tonnage 574,542; and the number of foreign ships 3,662, and their tonnage 574,542. The shipping of the navy may perhaps be estimated at 4,000,000l. making, with the former sum, 16,000 000l. to which some addition should be made for the value of the small craft employed on our rivers and canals.

The quantity of money in the country has, at different times, been a subject of dispute, and has never been determined with precision. However, by the recoinage in 1773, 1774, and 1776, it was found, that the value of the light gold delivered into the bank amounted to 15,563,593l.; and it was generally admitted that somewhat more than two millions of heavy guineas remained out in circulation, which with the silver and copper coin, made the whole, at that time, about 20 millions, at which sum Mr. Chalmers estimated it in the year 1786. Mr. Grellier estimates it at about 25 millions.

Of the value of the merchandize and manufactures usually in the hands of the merchants, wholesale dealers, shop-keepers, and manufacturers, it is very difficult to form a satisfactory idea. The total amount of the exports in 1797 was 28,917,000l. and of imports 21,013,000l. according to the custom-house accounts; but these accounts being considerably below the true value, if we take the whole as rated only 60 per cent. under the value in 1800, the annual amount of foreign trade estimated for that period, will be 79,880 000l. to which some addition should be made for smuggled goods. Mr. Pitt, in 1799, computed the imports at 25,000,000l. and the exports at more than 33,000,000l.; and in Feb. 1801, the foreign exports at 17,000,000l. and the domestic at 20,000,000l., amounting to a total of 37 000 000l. The official value of all imports on an average of six years, ending the 5th of January, 1804, was 29 490 945l.; and the official value of British manufactures exported, on the same average to the same time, was 23,834,340l.; and real value 40,100,870l.; and the official value of foreign merchandize exported, on the same average, to the same time, was 15 323,500l.; and the real value 9 323,257l. It was the opinion of a numerous meeting of merchants in March, 1797, that there is always, at the least, two months' supply of export and import merchandize in the custody of the merchants and traders, which, according to the above total of 79,888,000l. will amount to 13,314,666l. to which some addition should be made for property in the hands of foreign merchants. But the value of goods in the hands of manufacturers and retail traders far exceeds this sum. The official value of British manufactures exported in 1798 was 19,771,510l.; but this being at least 71 per cent. below the real value, we may take the actual value, on an average of two years, at 31 356,793l., which, it is presumed, cannot be more than a third of the whole produce of our manufactures; and accordingly, this will amount to 94,070,379l. If we deduct 5,000,000l. for that small part which is supposed to be in the hands of the merchants, the remainder will be 89,070,379l.; and of this it is probable that there is much more than three months' supply in the hands of the manufacturers and retail traders, which estimated in this proportion, amounts to 22,267,594l.

As to the value of that part of the property of individuals which consists in household furniture, wearing apparel, provisions, fuel, carriages, &c. &c. we can recur only to conjecture; but it may be thought not to be over-rated at three times the yearly rent of the houses which contain it, or 26,026,000l. in the whole of Great Britain.

The following summary will exhibit the results of the above estimates:

Value of the land of Great Britain	£ 990,000,000
Houses -	170,000,000
Cattle, and all kinds of farming stock -	102,000,000
Shipping, navy, and merchant ships	16,000,000
Money - - - - -	25,000,000
Goods in hands of merchants and wholesale dealers - - - - - -	13,314,000
Goods in hands of manufacturers and retail-traders - - -	22,267,000
Furniture, apparel, &c. - -	26,026,000
Total	£ 1,364,607,000

From the above ſtatement it appears that, ſince the year 1664, there has been an average gain of upwards of four millions per annum, of which a very conſiderable part has been derived, directly or indirectly, from foreign commerce. The great increaſe of the annual income affords a further proof that there muſt have been ſuch an accumulating ſurplus. Sir W. Petty (Pol. Arith. p. 123.) ſuppoſed the income derived from land to be 8,000,000l. the profits of perſonal eſtates 8,000,000l. and the profits of all kinds of labour 26,000,000, making together 42,000,000l. Mr. G. King eſtimated the whole income at 43,500,000l. Dr. Davenant, in 1701, ſtates the income derived from land at 10,000,000l. the profits of trade at 6,000,000l. and thoſe of ſciences, arts, labour, induſtry, manufactures, retailing foreign goods, and buying and ſelling home commodities, at 33,000,000l. making in the whole 49,000,000l. Theſe accounts are excluſive of Scotland; but after making a ſufficient addition for this country, it will appear that there has been a conſiderable increaſe of the general income. Sir John Sinclair, in his " Hints addreſſed to the Public," in 1783, obſerved, that the income of the country ariſing from lands, commerce, and manufactures, was commonly calculated at 100,000,000l. which he inclined to think a low valuation; and, without doubt, the profit derived of late years from each of theſe ſources has conſiderably increaſed. It is not eaſy to form a very preciſe eſtimate of the national income; but the following ſtatement is preſumed to be not very inaccurate:

From rent of lands . - - -	£. 33,000,000
——ditto of houſes - - - - -	8,500,000
Profits of farming, or the occupation of the land - - - - -	6,120,000
Income of labourers in agriculture -	15,000,000
Profits of mines, collieries, and inland navigations - - - - -	2,000,000
Profits of ſhipping in merchants' ſervice, and ſmall craft - - -	1,000,000
Income of ſtock-holders - -	15,500,000
From mortgages, and other money lent on private ſecurities -	3,000,000
Profits of foreign trade	11,250,000
Ditto of manufactures - - -	14,100,000
Pay of the army and navy, and ſeamen in merchants' ſervice - - -	4,500,000
Income of the clergy of all deſcriptions -	2,200,000
Income of the judges, and all ſubordinate officers of the law - - -	1,800,000
Profeſſors, ſchool-maſters, tutors, &c. -	600,000
Retail trades, not immediately connected with foreign trade or any manufacture	8,000,000
Various other profeſſions and employments	2,000,000
Male and female ſervants - - -	2,000,000
Total	£. 130,570,000

If the total expenditure be eſtimated at 125,860,000l., which has been deduced from a minute, and, perhaps, as accurate a ſtatement of particulars as the ſubject, admitting of various conjectures and preſumptions, allows, the difference between this expenditure and the general income ſhews the annual gain of the country, or the ſum applicable to the extenſion of commerce, the reſervation of a greater quantity of foreign articles, the increaſe of ſhipping and buildings, agricultural or mechanical improvements, or other augmentations of the general ſtock.

On introducing the income-tax, Mr. Pitt, chancellor of the exchequer, gave the following eſtimate of the annual income of Great Britain:

The land rental, after deducting one-fifth - - - - -	£. 20,000,000
The tenants' rental of land, deducting two-thirds of the rack-rent - -	6,000,000
The amount of tythes, deducting one-fifth - - - - - -	4,000,000
The produce of mines, canal navigations, &c. deducting one-fifth - -	3,000,000
The rental of houſes, deducting one-fifth	5,000,000
The profits of profeſſions - -	2,000,000
The rental of Scotland, taking it at one-eighth of that of England -	5,000,000
The income of perſons reſident in Great Britain, drawn from poſſeſſions beyond the ſeas - - -	5,000,000
The amount of annuities from the public funds, after deducting one-fifth for exemptions and modifications -	12,000,000
The profits on the capital, employed in our foreign commerce - -	12,000,000
The profits on the capital employed in domeſtic trade, and the profits of ſkill and induſtry - - - -	28,000,000
Total	£. 102,000,000

As one of the principal ſources of the wealth of Great Britain conſiſts in its manufactures, it may not be improper to give a brief ſtatement of them; reſerving a more copious detail for other articles in this dictionary, under which they will ſeparately occur. The woollen manufacture deſerves to be firſt mentioned, becauſe it is the moſt ancient, and, in a variety of reſpects, the moſt important ſtaple of the country. In an examination of the principal woollen manufacturers by a committee of the houſe of commons not long ago, the quantity of wool grown in this country was eſtimated at 600,000 packs of 240lbs. each, which, valued at 11l. per pack, amount to 6,600,000l.: and though the increaſe of value of manufactured wool is various, and depends on its quality, yet it was ſtated, that the total value of the wool manufacture in this country amounts to 19,800,000l. But the calculation ſuppoſes, that the number of ſheep, in 1791, was 28,800,000, which exceeded the truth at that time, and much more ſince that period; and it was formed upon an unuſually high price of wool. But the eſtimate will be much leſs objectionable, if it be formed on 500,000 packs at 10l. 10s. per pack, and thus the value of the wool will be 5,250,000l., and its manufactured value will be 15,750,000l. The average value of woollen goods exported for 1797, 1798, and 1799, is 6,104,211l. which, as the cuſtom-houſe values of goods exported are much below their real value, requires an addition of about 25 per cent. and thus it becomes 7,630,263l. The value of goods retained for home conſumption will be nearly equal to that of ſuch as are exported; and, therefore, the whole value of the manufacture appears to be about 15,260,000l. and may be taken, at a medium, between this ſum and that before ſtated, at 15,500,000l. Deducting 10 per cent. on the coſt of the goods, for the profits of the manufacturer, with intereſt of his capital, there will remain 14,090,909l. for the coſt of materials and wages of labour: and as the value of the wool is about 5,250,000l.; the amount of workmanſhip, or the wages of all the perſons employed in this manufacture, is 8,840,909l.; and the whole number of perſons employed, averaging their wages at 8s. each per week, does not exceed 425,043.

The value of the leather manufacture may be ſtated at 10,500,000l. from which deducting 954,545l. for the profits of the capital, and 3,500,000l. for the coſt of the raw

article, there will remain 6,045,455l. for the wages of persons employed in it, which, allowing to each 25l. a year at an average, makes the number employed 241,818.

The cotton manufacture was formerly inconsiderable, in comparison with its present state. The total quantity of cotton wool imported into England, on an average of five years, ending with 1705, was 1,170 881lbs.; and so late as the year 1781, it amounted to only 5,101,920lbs. But this manufacture was so much extended, that before the commencement of the last war the consumption of cotton wool amounted to upwards of 30,000,000lbs. per annum. During the years 1796, 1797, 1798, and 1799, the annual import, at an average, was 30,434,000lbs.; the value of which, when manufactured, cannot be less than 9,500,000l.; and if we deduct from this sum 863,636l. for profits of capital, at 10 per cent. and 3,804,250l. for cost of the raw material at 2s. 6d. per pound, there will remain 4,832,114l. for wages, which, divided at the rate of 15l. per annum for each person, on account of the number of women and children employed, makes the whole number 322,140 persons.

The silk manufacture has of late years experienced little fluctuation; the average of raw and thrown silk imported for three years preceding the 5th of January, 1797, was 883,438lbs.; and the usual quantity cannot be stated at less than 900,000lbs. the value of which, when manufactured, is about 2,700,000l. The cost of the silk, averaging that of the raw and thrown at 28s. per pound, amounts to 1,260.000l., and the profits of the manufacturer to 245,454l. at the rate of 10 per cent. on the cost when manufactured. The number of persons employed in this manufacture has been stated at 200,000 and upwards; but there is reason, says Mr. Grellier, to believe that it does not exceed 60,000 of all descriptions.

The linen manufacture of Great Britain is chiefly confined to Scotland, though some branches of it are carried on in Manchester and other parts of England. The total quantity of British linen exported during the years 1797, 1798, 1799, was 56,481,000 yards; and if the quantity retained for home consumption is not greater than the export, the value of the whole must be at least 1,600,000l.; and that this does not exceed the truth is probable, if the yearly value of the whole manufacture in Great Britain, with the thread and other branches of the flax trade, is stated at 2,000,000l., and the number of persons employed at 60,000.

The hemp manufacture at present exceeds 1,500,000l., but it is less in time of peace; and the number of persons employed is probably not less than 35.000.

The paper manufacture has of late greatly advanced. About 100 years ago, the paper made in this country was almost wholly the coarse wrapping paper, and for a long time the superior kinds were for the most part imported; but the export is now considerable. The annual value of the manufacture, at the present high prices of the article, cannot be less than 900,000l.; and the number of persons employed is 30,000.

The glass manufacture has of late very much improved and increased; so that it may now amount to 1,500,000l. and the persons employed in it are about 36.000.

The potteries and manufactures of earthen ware and porcelain have rapidly advanced during the present century, in consequence of the improvement they have received, and the introduction of many new and beautiful wares both for our own use and foreign markets. We are particularly indebted to Mr. Wedgwood, "for converting clay into gold." The annual value will probably not be over-rated at 2,000,000l., and the number of persons employed at 45,000.

The iron manufacture is supplied partly by the produce of our own mines, and partly by those of other countries. With respect to the first it is said, the total produce of pig-iron in Britain does not at present exceed 100,000 tons, and reckoning on an average, that 33 cwt. of crude iron produces one ton of bars, and that the manufacture of malleable iron amounts to 35,000 tons per annum, this branch will require 57,750 tons of crude iron; and the value in bars at 20l. a ton is 700,000l.; the remaining 42,250 tons, cast into cannon, cylinders, machinery, &c. at 14l. a ton, is worth 591,500l. The supply of foreign bar iron is chiefly obtained from Russia and Sweden; and the quantity imported, on an average of 12 years, has been 44,135 tons, worth, at 22l. per ton, 970,970l., which, together with the former sums, amounts to 2,262,470l. Some years ago, the value of the iron manufacture was estimated at 8,700,000l.; but if this sum should appear too high, we may include tin and lead, and the value of the whole will probably amount to 10,000,000l., and the number of persons employed to 200,000.

The copper and brass manufactures are now established in this country. Till about the years 1720 or 1730, most of the copper and brass utensils used for culinary and other purposes in this country were imported from Hamburg and Holland, being procured from the manufactories of Germany: and even so late as the years 1745 and 1750, copper tea-kettles, saucepans, and pots of all sizes, were imported in large quantities. But by the persevering industry, capitals, and enterprising spirit of our miners and manufacturers, these imports have become totally unnecessary; so that the articles are now all made here, and far better than any other country can produce. The discovery of new copper-mines in Derbyshire and Wales, about the year 1773, contributed to the extension of the manufacture in this country; and it appears to be still increasing, notwithstanding the late great advance in the price of copper. The value of wrought copper and brass, exported during the year 1799, was 1,222,187l.; and there is reason to believe that the whole value of these manufactures at present is at least 3,500,000l., and the number of persons employed 60,000.

The steel, plating, and hard-ware manufactures, including the toy-trade, have been of late much extended, and may probably amount in value to 4,000,000l., and the persons employed to at least 70,000.

It is acknowledged, that many of these estimates must be essentially defective, from the want of public documents respecting many important branches of trade. However, they serve to shew, in a general view, the relative extent of our principal manufactures, as in the following summary:

	Annual Value.	Persons employed.
Woollen - -	£. 15.500,000	425,043
Leather - -	10,500,000	241,818
Cotton - -	9,500,000	322,140
Silk - - -	2,700 000	60,000
Linen and flax -	2,000,000	60,000
Hemp - -	1,500 000	35,000
Paper - -	900,000	30,000
Glass - - -	1,500,000	36,000
Potteries - -	2,000,000	45.000
Iron, tin, and lead	10,000,000	200,000
Copper and brass -	3.500,000	60,000
Steel, plating, &c. -	4,000,000	70,000
	£. 63,600,000	1,585,000

To the above enumerated manufactures of greater importance, we might have added those of hats, horn, straw, &c. which taken together are of very considerable amount, and employ a great number of hands. There are also some, which, though not generally included among the manu-

factures, partake of the nature of thefe, and might, not improperly, be claffed with them. To this head we might refer the elegant branch of exportation, or that of beautiful prints, for which this country is in an eminent degree indebted to the late alderman Boydell. Grellier, Month. Mag. Jan. 1801.

The commerce of Great Britain extends through the eaftern and weftern hemifpheres of the globe, by means of the capital and credit of the country, the fkill and induftry of its artizans and manufacturers, the number of its fhips and the character of its feamen, and the enterprifing fpirit as well as eftablifhed reputation of its merchants. The number of regiftered veffels belonging to the Britifh dominions, and employed in trade in 1802, was 20,568, their tonnage 2,128,055, and the number of feamen navigating the fame, 154,530. In 1803, the number of veffels was 21,445; their tonnage 2,238,249; and the number of men 155,445; being an increafe of 877 fhips, of 110,194 tons, and of 915 men.

The following table will exhibit a complete view of Britifh commerce folely from the port of London, for one year, ending Jan. 5, 1795, fince which the commerce has increafed.

Names of the Countries.	Value of Imports into London.			Value of Exports from the Port of London, to Foreign Parts. British Manufactures.			Foreign Merchandize.		
	£.	s.	d.	£.	s.	d.	£.	s.	d.
Ireland	2,209,501	3	4	168,687	18	3	914.352	4	4
Britifh Weft Indies	6,072,117	5	0	2,249,043	13	11	579,453	6	0
Conquered Iflands	1,226,064	13	8	260,976	0	11	110,817	18	0
Britifh American Colonies	307,412	13	0	654,842	19	4	251,551	6	2
Guernfey and Jerfey	91,936	1	2	12,001	13	10	21,616	16	8
Gibraltar	12,947	16	8	83.473	14	11	69,315	2	8
Honduras Bay	14,696	4	2	2,029	18	11	2,550	16	2
South Fifhery	197,680	8	6	21	6	8	—	—	—
Afia, including Eaft Indies	8,916,950	2	10	3,398,680	1	4	185,190	16	0
Africa	66,013	8	4	90,593	12	9	188,743	16	6
Turkey	641,860	19	2	32,065	12	0	123,776	7	2
Streights	8,399	14	0	—	—	—	—	—	—
Venice	82,107	16	0	6,203	17	11	16,305	7	2
Italy	1,215,012	15	0	80,980	18	9	340,786	0	8
Spain	1,070,697	18	0	205,096	4	4	265,169	3	4
Portugal	644,600	3	8	182,780	6	2	119,813	12	6
Madeira	7,479	16	8	27,998	6	10	6,886	18	2
Canaries	6,763	19	10	20,116	18	4	377	5	2
France	130	6	8	3,216	5	3	63,625	10	6
Auftrian Flanders	137,249	5	0	129,413	9	7	887,642	18	10
Holland	1,203,515	3	6	114,458	3	7	1,968,687	3	4
Germany	1,089,307	19	4	1,044,634	18	0	6,176,100	14	8
Pruffia	196,657	3	2	54,380	14	0	272,719	17	4
Poland	104,978	10	4	7,022	11	10	57,067	2	4
Sweden	262,727	3	4	33,845	5	6	111,457	14	4
Ruffia	1,269,688	9	6	95,519	8	8	491,244	9	2
Denmark and Norway	166,366	1	0	147,340	0	11	545,509	19	8
Greenland	26,753	11	2	—	—	—	—	—	—
United States of America	811,511	18	8	2,251,280	12	1	429,248	7	8
Florida	16,239	16	0	38,067	0	3	8,855	0	0
Foreign Weft Indies	56,240	2	0	1,767	13	10	60	0	0
Prize Goods	1,572,868	8	8				Included in the account of each country.		
	29,706,476	17	4	11,396,539	13	8	14,208,925	14	6

RECAPITULATION.

	£.	s.	d.	£.	s.	d.
The aggregate value of goods imported into London in one year				29,706,476	17	4
Britifh manufactures exported	11,396,539	13	8			
Foreign merchandize, do.	14,208,925	14	6			
				25,605,465	8	2
Value of goods imported in upwards of 9000 coafting veffels, averaged at 500l. each.	4.500,000	0	0			
Value of goods exported coaftways, in about 7000 veffels, at 1000l. each.	7,000,000	0	0			
				11,500,000	0	0
Total amount of property fhipped and unfhipped in the river Thames, in the courfe of a year, eftimated at				66,811,942	5	6

If we add to this eſtimate, the accounts belonging to the other ports of Briſtol, Liverpool, &c. the account muſt be enormous.

From the ſtates of North America are chiefly imported tobacco, rice, indigo, timber, hemp, flax, iron, pitch, tar, and lumber; from the Weſt Indies, ſugar, rum, cotton, coffee, ginger, pepper, guaiacum, ſarſaparilla, manchineal, mahogany, gums, &c.; from Africa, gold duſt, ivory, gums, &c.; from the Eaſt Indies and China, tea, rice, ſpices, drugs, colours, ſilk, cotton, ſaltpetre, ſhawls, and other products of the loom; from our remaining ſettlements in North America, furs, timber, pot-aſh, iron; and from the various ſtates of Europe, numerous articles of utility and of luxury. Pinkerton's Geog. vol. i. p. 100.

For other particulars relating to Great Britain, ſee CONSTITUTION, DEBT, FUND, PARLIAMENT, REVENUE, &c. &c. See alſo ENGLAND, SCOTLAND, and WALES.

Buddle

BUDDLE, in *Mineralogy*, a name given by the English dreffers of the ores of metals, to a fort of frame made to receive the ore after its firft feparation from its groffeft foulnefs.

The ore is firft beaten to powder in wooden troughs, through which there runs a continual ftream of water, which carries away fuch of it as is fine enough to pafs a grating, which is placed at one end of the trough; this falls into a long fquare receiver of wood, called the *launder:* the heavieft and pureft of the ore falling at the head of the launder, is taken out feparately, and requires little more care or trouble; but the other part, which fpreads over the middle and lower end of the launder, is thrown into the buddle, which is a long fquare frame of boards, about four feet deep, fix long, and three wide; in this there ftands a man barefooted, with a trampling fhovel in his hand, to caft up the ore about an inch thick, upon a fquare board placed before him as high as his middle; this is termed the *buddle-head;* and the man dexteroufly, with one edge of his fhovel, cuts and divides it longwife, in refpect of himfelf, about half an inch afunder, in thefe little cuts; the water coming gently from the edge of an upper plain board, carries away the filth and lighter part of the prepared ore firft, and then the metalline part immediately after. all falling down in the buddle, where, with his bare feet, he ftrokes it and fmooths it, that the water and other heterogeneous matter may the fooner pafs off from it.

When the buddle by this means becomes full, the ore is taken out; that at the head part, being the fineft and pureft, is taken out feparate from the reft, as from the launder. The reft is again trampled in the fame buddle; but the head, or, as it is called the forehead, of this buddle, and of the launder, are mixed together, and carried to another buddle, and trampled as at firft. The foreheads of this laft buddle, that is, that part of the ore which has fallen at the head, is carried to what they call a drawing buddle, whofe difference from the reft is only this, that it has no tye, but only a plain floping board, on which it is once more wafhed with the trampling fhovel. Tin-ore, when it is taken from this, is called black tin, and this is found to be completely ready for the blowing-houfe. Phil. Tranf. N° 69. See *Dreffing of* ORE.

Button

BUTTON, in its moft ordinary acceptation, fignifies a well known appendage to garments for conveniently faftening them together.

Trifling as this article may appear to fome of our readers to be in itfelf, there is certainly no manufacture which includes fuch an infinite variety of operations as that of the button-maker. The number of fubftances of which they are made is almoft inconceivable, and each requires a diftinct fet of manipulations. Amongft them are gold, filver, plated copper, white-metal, pinchbeck, fteel, japanned, tin, glafs, foil ftones, mother of pearl, ivory, bone, horn, tortoife-fhell, jet, cannel coal, paper, leather, and a thoufand others; exclufive of thofe buttons which confift of a mould of wood or bone covered with filk or mohair, and the manufacture of which belongs to a different clafs of artifans. It would very

very far exceed the limits of a work like the present if we were to enter into all the details of so multifarious a business as this: we shall therefore only trace a few outlines of the processes most ordinarily in use.

Of the manufacture of metal buttons. These are originally formed in two different ways; the blanks are either pierced out of a large sheet of metal with a punch driven by a fly-press, or cast in a pair of flasks of moderate size, containing 10 or 12 dozen each. In this latter case, the shanks are previously fixed in the sand, exactly in the centre of the impression formed by each pattern, so as to have their extremities immersed in the melted metal when poured into the flask, by which means they are consequently firmly fixed in the button when cooled. See FOUNDERY. The former process is generally used for yellow buttons, and the latter for those of white metal.

We shall first give an instance of the former mode of procedure as used in the manufacture of gilt buttons. The *gilding metal* is an alloy of copper and zinc, containing a smaller proportion of the latter than ordinary brass, and is made either by fusing together the copper and zinc, or by fusing brass with the requisite additional proportion of copper. This metal is first rolled into sheets of the intended thickness of the button, and the blanks are then pierced out as before mentioned. The blanks thus formed, are, when intended for plain buttons, usually planished by a single stroke of a plain die driven by the same engine, the fly-press: when for ornamented buttons, the figure is frequently also struck in like manner by an appropriate die, though there are others which are ornamented by hand. The shanks, which are made with wonderful facility and expedition by means of a very curious engine, are then temporarily attached to the bottom of each button by a wire clamp like a pair of sugar-tongs, and a small quantity of solder and resin applied to each. They are in this state exposed to heat on an iron plate containing about a gross, till the solder runs, and the shank becomes fixed to the button, after which, they are put singly in a lathe, and their edges turned off smoothly.

The surface of the metal, which has become in a small degree oxidated by the action of the heat in soldering, is next to be cleaned, which, in this, as in a great variety of other instances in the manufacture of metallic articles, is effected by the process of *dipping* or *pickling;* that is, some dozens of them are put into an earthen vessel pierced full of holes like a colander; the whole dipped into a vessel of diluted nitric acid; suffered to drain for a few seconds; again dipped successively into four or five other vessels of pure water, and then dried.

The next operation is the *rough burnishing*, which is performed by fixing the buttons in the lathe, and applying a burnisher of hard black stone from Derbyshire: the minute pores occasioned by the successive action of the heat and the acid are thus closed, and the subsequent process of gilding considerably improved, both with regard to economy and perfection.

The first step towards the gilding of all the alloys of copper consists in covering the surface uniformly with a thin stratum of mercury, by which means the amalgam, which is afterwards applied, attaches itself to it much more readily than it would otherwise do. This part of the process is called *quicking*, and is effected by stirring the buttons about with a brush in a vessel containing a quantity of nitric acid supersaturated with mercury; which latter is, of course, by the superior elective attraction of the copper for the acid, precipitated in its metallic state on the buttons, whose surfaces become uniformly and brilliantly covered with it. The mercury which hangs in loose drops on the buttons is then shaken off by jerking the whole violently in a kind of earthen colander made for the purpose; and they are then ready for receiving the amalgam.

The amalgam is made by heating a quantity of grain gold with mercury in an iron ladle, by which means the former is soon dissolved, and the whole is then poured into a vessel of cold water. The superabundant mercury is strongly pressed out through a piece of chamois leather, and the remaining amalgam, which is of about the consistence of butter, is then fit for application.

This is performed by stirring the buttons, whose surfaces are already thinly covered, or wetted with mercury, in an earthen vessel with the requisite proportion of amalgam and a small quantity of diluted nitric acid, by which means the amalgam also attaches itself to their surfaces with a considerable degree of equality. The necessary quantity of gold is about five grains to a gross of buttons of an inch in diameter.

The next process is the volatilisation of the mercury by heat, which is usually called by the workmen *drying off*. This is performed by first heating the buttons in an iron pan, somewhat like a large frying pan till the amalgam with which they are covered becomes fluid, and seems disposed to run into drops, on which they are thrown into a large felt cap, called a *gilding cap*, made of coarse wool and goat's hair, and stirred about with a brush to equalize the covering of the surface by the gold. After this, they are again heated, again thrown into the gilding cap and stirred, and these operations successively repeated till the whole of the mercury is volatilised. This part of the process, as will readily be conceived, is extremely unwholesome, and has the most terrible effects on the constitution of the workmen, so that it would be no small desideratum, (and it does not seem to be difficult), conveniently to effect this agitation and friction of the heated buttons in a covered vessel; in which case also, though of inferior importance, the volatilised mercury might be saved. For preventing the waste and injury attending this process, an apparatus resembling that delineated in *Plate* II. *Miscellany*, *fig.* 1. has been partially and successfully adopted by Mr. Mark Sanders, an eminent button-maker of Birmingham.

"A hearth of the usual height is to be erected, in the middle of which a capacity for the fire is to be made; but instead of permitting the smoke to ascend into the top A, made of sheet or cast iron, through which the mercury is volatilised, a flue for that purpose should be conducted backwards to the chimney B. An iron plate, thick enough to contain heat sufficient to volatilise the mercury, is to cover the fire-place at the top of the hearth C. There must be an ash-hole, D, under the fire-place. The square space E, seen in the fire-place, is the flue, which serves to carry the smoke back under the hearth into the chimney B. The door of the fire-place and ash-pit may either be in front, as represented in the plate, or at the end of the hearth at F, which will perhaps less incommode the work-people. It would be of great advantage if the space between A and the iron plate C was covered up with a glass window coming down so low as only to leave sufficient room for moving the pan backwards and forwards with facility. If the sides were also glass instead of brick-work it would be still better, as the work-people would be able to have a full view of their work without being exposed to the fumes of the mercury, which, when volatilised by heat communicated to the pan by the heated iron plate over the fire-place, would ascend into the top A, appropriated for its reception, and descend into the tub G, covered at top and filled pretty high with water. By this means the hearth would, in fact, become a

distilling apparatus for condensing and recovering the volatilised mercury. In the tub G the principal part would be recovered; for, of what may still pass on, a part would be condensed in ascending the tube H, and fall back, while the remainder would be effectually caught in the tub or cask I, open at the top, and partly filled with water. The latter tub should be on the outside of the building, and the descending branch of the tube H should go down into it at least 18 inches, but not into the water. The chimney or the ash-pit should be furnished with a damper to regulate the heat of the fire.

The water may be occasionally drawn out of the tubs by a siphon, and the mercury clogged with heterogeneous matter may be triturated in a piece of flannel till it passes through, or placed in a pan of sheet iron, like a dripping pan, in a sufficient degree of heat, giving it a tolerable inclination, so that the mercury, as it gets warm, may run down and unite in the lower part of the pan. But the mercury will be most effectually recovered by exposing the residuum left in the flannel bag to distillation in a retort made of iron or of earthen ware.

When the mercury is volatilised from the buttons, or, as the workmen denominate it, when the buttons are dryed off, they are finally burnished, and are then finished and fit for carding.

The reader unacquainted with this branch of manufacture will be surprised to learn how far a small quantity of gold, incorporated with mercury, will spread over a smooth surface of copper. Five grains, worth one shilling and threepence, on the top of a gross, that is, 144 buttons, each of one inch diameter, are sufficient to excuse the manufacturer from the penalty inflicted by an act of parliament; yet many, upon an assay are found to be deficient of this small quantity, and the maker fined and the buttons forfeited accordingly. Many hundred grosses have been tolerably gilt with half that quantity; so extremely far can gold be spread, when incorporated with mercury, over the surface of a smooth piece of copper". Philosophical Magazine, N° 33. p. 19, &c.

The white metal buttons which are composed of brass alloyed with different proportions of tin, after having been cast as before mentioned, are polished by turning them in a lathe, and applying successively pieces of buffalo skin glued on wood, (or *buffs* as the workmen call them) charged with powdered grindstone and oil, rotten stone and crocus martis. They are then *white-boiled*, that is, boiled with a quantity of grain tin in a solution of crude red tartar, or argol, and lastly, finished with a buff with finely prepared crocus.

Glass buttons. These articles are also frequently wholly composed of glass of various colours in imitation of the opal, lapis lazuli, and other stones. The glass is in this case kept in fusion, and the button nipped out of it whilst in its plastic state, by a pair of iron moulds, like those used for casting pistol shot, adapted to the intended form of the button: the workmen previously inserting the shank into the mould so that it may become imbedded in the glass when cold.

Mother of pearl buttons. This substance is also frequently used in the manufacture of buttons; in which case, the mode of fixing in the shank is somewhat ingenious. It is done by drilling a hole at the back which is under-cut, that is, larger at the bottom than the top, like a mortise, and the shank being driven in by a steady stroke, its extremity expands on striking against the bottom of the hole, and it becomes firmly rivetted into the button. To these, foil-stones are also frequently added, in which case, they are usually attached with isinglass-glue. Steel studs are also often rivetted into buttons of this and various other kinds. See Foil-stones and Studs.

Shell buttons. This name is given to those buttons which consist of a back which is generally of bone without any shank, but corded with catgut, and covered in front with a thin plate of metal struck with a die. They are now, however, much less in use than formerly. The backs are cut out with a brace whose bit is a circular saw, like that of a surgeon's trephine, and the four holes through which the catgut passes are drilled by four drills moving parallel to each other, and acting at once. They are then corded by children who tie the catgut on the inside; the cavity is filled with melted resin, and the metal shell applied warm. The button is then pressed between two centres in a lathe, which are forced together by a weight acting on a lever, (an ingenious application of this engine frequently made use of in this manufacture), and the edge of the shell turned down during its revolution with a small burnisher.

In the year 1790, a patent was granted to Mr. Henry Clay of Birmingham for a new method of manufacturing buttons of slate, or slit stone; and in 1800, Mr. Joseph Barnett of the same place obtained a patent for an improved mode of making buttons, by fixing two shanks, or other fastening, on one button, one on each side, on the under surface, opposite to each other, instead of only one in the centre.

The practice of wearing buttons consisting merely of a mould covered with the same kind of cloth as the garment itself, being at present extremely general, it may perhaps be proper to remark, that this is prohibited on pain of pecuniary penalties, from 40s. to 5l. per dozen, by several statutes which have been made at different times for the promotion of this manufacture; and under which, several convictions have taken place within a few years. These are, 10 W. 3. c. 2. 8 Ann. c. 6. 4 Geo. c. 7. and 7 Geo. c. 12. The importation of buttons is prohibited on pain of forfeiture, and penalty of 100l. on the importer, and 50l. on the seller, by 13 & 14 C. II. c. 13. § 2. and 4 W. III. c. 10. § 2.

By 36 Geo. III. c. 60. any person putting false marks on gilt buttons, erasing any marks except such as express the real quality, or any other words, except *gilt* or *plated*, incurs the penalty of forfeiting such buttons, and also 5l. for any quantity not exceeding 12 dozen; and if above, after the rate of 1l. for every 12 dozen. The penalty, however, does not extend to those who mark the words *double* and *treble gilt*, provided, in the case of double gilt buttons, gold shall be equally spread upon their upper surface, exclusively of the edges, in the proportion of 10 grains to the surface of a circle 12 inches in diameter; and in that of treble gilt, the gold shall amount to 15 grains in the same proportion. The penalty on making false bills of parcels, expressing any other than the real quality of such buttons, is 20l.; and that on mixing buttons of different qualities, forfeiture of the same, and 5l. for any number between one and 12 dozen, and above this number, 1l. for every 12 dozen. In order to ascertain what shall be deemed gilt or plated buttons, gilt buttons shall have gold equally spread upon the upper surface in the proportion of five grains to the surface of a circle 12 inches in diameter; and plated buttons shall have the superficies of the upper surface made of a plate of silver fixed upon copper, or a mixture of it with other metals, previously to its being rolled into sheets or fillets. All pecuniary penalties may be recovered by action or suit within three calendar months, in the courts of Westminster, and one justice may, by warrant, cause metal buttons liable to

forfeiture, to be ſeized and kept in ſafe cuſtody, to be produced as evidence upon any action, or cauſe them to be deſtroyed. Pecuniary penalties may alſo be adjudged by two juſtices in the place where the offender reſides, or the offence is committed. This act, however, does not extend to buttons made of gold, ſilver, tin, pewter, lead, or mixture of tin and lead, or iron tinned, or of Bath or white metal, or any of theſe metals inlaid with ſteel, or buttons plated upon ſhells.

Calendar

CALENDER, a machine used, in the manufactories, for pressing certain stuffs, silks, callicoes, and even linens; to make them smooth, even and glossy. It is also used for watering, or giving the waves to tabbies and mohairs.

The word is formed from the French *calandre*, or Spanish *calandra*, which signify the same; and which some derive further from the Latin *cylindrus;* because the whole effect of the machine depends upon a cylinder. Borel derives the name from that of a little bird, of the swallow kind; on account of the agreement between the feathers of the bird, and the impression of the machine.

The calender consists of two large wooden rollers, round which the pieces of stuff are wound: these are put between two large, close, polished planks of wood, or plates of iron, the lower serving as a fixed base, and the upper moveable, by means of a wheel like that of a crane; with a rope, fastened to a spindle, which makes its axis: this upper part is of a prodigious weight, sometimes twenty or thirty thousand pounds. It is the weight of this part, together with its alternate motion, that gives the polish, and makes the waves on the stuffs, by causing the cylinders on which they are put to roll with great force over the lowest board. The rollers are taken off, and put on again by inclining the machine.

At Paris they have an extraordinary machine of this kind, called the *royal calender*, made by order of M. Colbert; the lower table or plank of which is made of a block of smooth marble, and the upper lined at bottom with a plate of polished copper.

This is called the great calender; they have also a small one with two tables of polished iron or steel.

There are also calenders without wheels, which are wrought by a horse harnessed to a wooden bar, which turns a large arbor placed upright; at the top of which, on a kind of drum, is wound a rope, the two ends of which being fastened to the two extremities of the upper plank of the engine, give it motion. But the horse calendar is in less esteem than the wheel kind, as the motion of this latter is more equable and certain.

We read of calendering worsteds. To improve linen farther, the drapers get several sorts of their cloths calendered: whereby their threads are made to lie flatter and smoother.

CALENDER also denotes the workman who manages the machine above described; applying the cloth or stuff underneath, after having first wound it on the rollers.

Camera

CAMERA *Æolia*, a contrivance for blowing the fire, for the fusion of ores, without bellows; by means of water falling through a funnel into a close vessel, which sends from it so much air or vapour as continually blows the fire: if there be the space of another vessel for it to expatiate in by the way, it there lets fall its humidity, which otherwise might hinder the work. The contrivance was named *camera Æolia* by Kircher. Hook, Phil. Coll. N° 3. p. 80. See BELLOWS,

CAMERA *lucida*, a contrivance of Dr. Hook for making the image of any thing appear on a wall in a light room, either by day or night. Opposite to the place or wall where the appearance is to be, make a hole of at least a foot in diameter, or if there be a high window with a casement of this dimension in it, this will do much better without such hole, or casement opened. At a convenient distance, to prevent its being perceived by the company in the room, place the object or picture intended to be represented, but in an inverted situation. If the picture be transparent, reflect the sun's rays by means of a looking glass, so as that they may pass through it towards the place of representation; and to prevent any rays from passing aside it, let the picture be encompassed with some board or cloth. If the object be a statue, or a living creature, it must be much enlightened by casting the sun's rays on it, either by reflection, refraction, or both. Between this object and the place of representation put a broad convex glass, ground to such a convexity, as that it may represent the object distinctly in such place. The nearer this is situate to the object, the more will the image be magnified on the wall, and the further the less; such diversity depending on the difference of the spheres of the glasses. If the object cannot be conveniently inverted, there must be two large glasses of proper spheres, situate at suitable distances, easily found by trial, to make the representations erect. This whole apparatus of object, glasses, &c. with the persons employed in the management of them, are to be placed without the window or hole, so that they may not be perceived by the spectators in the room, and the operation itself will be easily performed. Phil. Trans. N° 38, p. 741, seq.

CAMERA *Obscura*, or DARK CHAMBER, in *Optics*, a machine or apparatus so constructed, that principally by means of a convex glass, or a convex glass and plane mirror, the images of external objects are represented on a rough ground plane glass, white paper, white wall, or other surface, in the most vivid and distinct manner, with all their natural motions, colours, shades, &c. The first invention of the camera obscura has been ascribed to Baptista Porta.—See his Magia Naturalis, lib. xvii. cap. 6. first published at Frankfort about the year 1589 or 1591. The first four books of this work were published at Antwerp in 1560. But Dr. Freind, in his "History of Physic," (vol. ii. p. 236) observes, that friar Bacon, who flourished in the beginning of the 13th century, describes the camera obscura, and all sorts of glasses, which magnify or diminish any object, bring it nearer to the eye, or remove it farther off. See also Bacon's "Opus Majus" by Dr. Jebb, p. 2[illegible]6; and his Epistle "ad Parisienses," and his "Perspective" cited by Dr. Plott in his "History of Oxfordshire," p. 21[illegible]: from which we may conclude, that he had a very accurate and extensive acquaintance with the properties of various kinds of glasses.

CAMERA *Obscura, the use of the*, is manifold: it assists very much in explaining the nature and rationale of vision, and hence

hence by some it has been compared to the artificial eye. It exhibits the most striking and entertaining representations of objects of all descriptions, whether near or distant, in their true perspective, the colouring just and natural, their light and shadows correct, and all their motions and relative positions according to the original. By means of this instrument, a person however unacquainted with drawing, may delineate objects with great facility and correctness; and to the skilful artist it will be found indispensably useful in comparing his sketches with the perfect representations given in the camera, and by observing his defective imitations, he may correct, as much as possible, his designs. To the delineations of that beautiful representation called the *Panorama*, this instrument has proved of essential use.

Camera *Obscura, the theory of the*, is contained in the following proposition.

If an external object, as A, *Plate* III. *Optics*, *fig.* 1, radiates its light through a small aperture C, in a shutter of a perfectly darkened room upon a white paper or painted screen opposite to it, an image of the object will be depicted on the screen in an inverted position. For the aperture C being supposed very small, the rays issuing from the point B will fall on *b*: those from the points A and D will fall on *a* and *d*; wherefore, since the rays issuing from the several points are not blended, they will, by reflection, exhibit its appearance on the screen. But since these rays, A C and B C, intersect each other in the aperture, and the rays from the lowest points fall on the highest, the situation of the object will necessarily be inverted. Hence, since the angles at D and *d*, and the vertical ones are equal at C, B and *b*, and A and *a*, will be also equal; consequently, if the screen where the object is delineated be parallel to it, *a b* : A B :: *d* C : DC.

That is, the height of the image will be to the height of the object, as the distance of the image from the aperture is to the distance of the object from the same. This proves, therefore, that the inversion of the object is not owing to any lens that may be used in a camera obscura. In this manner, the figures of the image are very faint and confused, for want of a due degree of light, and its proper refractions.

Camera *Obscura, construction of a*, whereon the images of external objects are distinctly represented in their genuine colours, light and shade, &c. and either in an erect or inverted position.

1. Darken, in the most perfect manner possible, a room or chamber; in the shutter of one of the windows that faces the object to be represented, cut a small circular aperture, see *fig.* 1. C.

2. In this aperture fix either a double or plain convex lens; if the latter, with the convex side next the object. Its focus may be of any length between 3 and 6 feet.

3. At a proper distance, to be determined by experiment, or about the focal distance of the lens, place perpendicularly a large surface of white paper or cloth, and on this the images of the external objects directly before the lens will be beautifully delineated, but in an inverted position. The paper or cloth should be moveable, so that the exact distance of the focus of the lens may be obtained, or the images will not be shewn with their utmost distinctness. Those objects also should be selected that are in the strongest light, or illuminated by the sun's rays. In northern latitudes at noonday, a window opposite the north is best; in the morning, facing the west, and in the evening facing the east. In southern latitudes a window facing the south is best at noon. The shorter the focus the smaller and brighter the images will appear; and the longer, the larger the objects; but if the focus be very long, from 20 to 30 feet, the same light being more dilated or spread over a large surface, the images will appear somewhat obscure, and the colouring fainter. The images will be still brighter if the spectator first stay a quarter of an hour in the dark.

This is the most perfect method of obtaining a representation of objects, from having but one refracting medium, but in some cases the inverted position of the images may be some objection; to obviate which, the following methods may be used to make the picture erect. Hold a true ground plain mirror slantwise against your breast, under an acute angle, and looking therein, you will see all the images restored to their natural and erect position, and with an addition of lustre that they will receive from the reflection of the mirror. Or, which is a better way, and does not require a mirror near so large, place a mirror above and rather near the lens, so as to reflect the rays down upon a white surface, a screen directly under, or parallel to the mirror. Or, a large concave mirror may be placed before the picture, at such a distance that the image of the picture may appear before the mirror, which will then be erect, and appear pendant in the air. Another method, which is more direct, is by placing another convex lens in a partition behind the paper or screen, with the image at twice the focal distance of the said lens, the axes of the two lenses coinciding, in which case another picture of the images will be formed but erect, as large as the first, but not so bright, and with a contracted field or extent of the picture. Or, two lenses of short foci in draw-out tubes, may be applied to the hole in the shutter instead of one, which will also produce an erect position of the images, but the light will be less, the extent very limited, and serve only for the representation of busts, small figures, &c. as hereafter to be described. This method is but of little use and seldom practised.

The following description of cameras obscuras has been communicated to us by Mr. William Jones, optician, Holborn, as being the most commodious and perfect, and what have been preferred, and are in general use, by the most skilful artists:—

Fig. 2. represents the scioptic ball, which is made of mahogany, and consists of three parts, a frame, a ball, and a lens. The frame consists of two pieces in a circular screw rim, fitted one to the other, and both so excavated as to admit, and keep steady a spherical ball perforated, which is voluble in its frame more or less easily, as the parts of the frame are less or more screwed together. At each end the hole in this ball is a screw cell for containing a lens; these lenses are of different focal lengths, and only one is to be used at a time, when the images are to be formed. The frame of this scioptic ball is to be screwed fast to the window shutter or window board of a well-darkened room, before a hole previously made therein. There are two brass nuts and screws, *a*, *b*, fitted to the frame for that purpose; the nuts are screwed to the shutter or board, so that by means of the screws the scioptic ball may be the more readily attached to, or detached from, the shutter. This apparatus is very convenient, when experiments by a variety of lenses may be desired. A, *fig.* 2, represents the position of a mirror when applied for reflecting downwards the images in order to obtain the erect positions; if the frame be made to turn on an hinge, it will be the more useful to direct the image to an oblique screen, or table, as may be required. *Fig.* 1. represents a darkened room with a lens attached to the side or shutter, or where the scioptic ball is to be placed. E represents the moveable white paper screen that receives the images of the objects formed by the lenses, and is moveable to the distance of the focal length of the glass. A B shews the manner in which the bust, sta-

tue, or picture, may be fixed on a support on the outside of the window, so that an image may be formed upon the paper within, from which the artist is to copy or delineate. For such proximate objects the focus of the lens must be short, from 9 to 12 inches, or the screen will be required to be at too remote a distance from the lens. When the distance of the object and the image are the same from the lens, the image will be of the same size as the object. When the object approaches nearer, the image will recede and enlarge, and *vice versâ*.

To exhibit Solar Phenomena by means of the Scioptic Ball and Socket.

The scioptic ball affords a very convenient method of forming an image of the sun in the darkened room. If a lens 10 or 12 feet focus be placed on it, and a white paper screen placed at its focus, in a perpendicular position to the rays, a distinct image of the sun will be formed, about one inch diameter, on which will be conspicuously exhibited all the spots or solar maculæ. At the time of a solar eclipse, the whole progress of the moon, from the time of the first contact of the limbs to the last, may, in this way, be observed very distinctly. But the best method is by connecting a draw-out telescope, with the ball of the socket, *fig.* 2. by screwing the end with the object glass to it, and taking out all the eye glasses at the other end, except the one next to the eye, then moving inwards the first tube till the image of the sun appear distinct; and you will have a bright image from 12 to 20 inches diameter, according to the distance of the screen, which will, to any number of spectators, exhibit the solar phenomena intended to be viewed.

Construction of a Chamber Camera Obscura.

The foregoing is the readiest and most simple method of converting a room into a camera obscura, but it is attended with these objections, that it only serves for objects directly facing the lens, and occasions always the trouble of darkening the room, fixing and adjusting the apparatus, &c. *Fig.* 3. represents a roof shaded like a dome or cupola, placed over a building, prospect-room, or temporary room erected for the purpose of a camera obscura, and in this way affords the most ready and advantageous plan for all surrounding objects. The whole dome A B may be made to turn round on friction wheels, in a groove made in the roof for that purpose, and to carry round with it the glasses in the box C above, or which, in some cases, is a more manageable way, the box with the glasses is made moveable in a groove round upon the dome, and is turned by means of a long rod by a person within. The manner of fabricating such a dome and box will be evident to any good joiner by a mere inspection of the figure. The mahogany box C is of a cubical form about 6 or 7 inches in the length of a side; a true ground mirror in a frame is placed diagonally in the box, and is moveable somewhat on an axis at its lower edge upwards and downwards, to reflect the rays from objects at various distances; underneath this mirror, in a round cell, at the bottom of the box, is fixed a double convex lens, about 6 or 8 feet focus, and 4 or 4½ inches in diameter: this lens will form upon a white table D, placed on the floor below, the images of the objects reflected by the mirror above, at the focal distance of the lens. The diameter of this table should be 2½ or 3 feet, excavated on its surface to a small degree of concavity, or from a radius about the focus of the lens, in order, that the inequality of the distance of its surface from the centre of the lens, presenting the images indistinct at the circumference, when they are clear in the middle, may be obviated. The surface must be painted perfectly white, or, which is better, covered with a thin coating of plaster or stucco. The pillar of the table should be made with a screw working in a female one out in the pedestal, so that by turning round the table and screw its surface may either be elevated or depressed, as may be necessary, to admit of the clearest and best defined picture of the images possible. To persons having dwellings upon elevated situations commanding extensive prospects over countries, rivers, the sea, &c. a machine of this kind constructed over it will afford more delight and entertainment, as well as use to an artist, than any person would imagine, who had not previously been a witness to such an effect. To those who may not wish to be at the expence of a dome, Mr. Jones recommends the box fitted to a wooden pyramidical trunk, (see *fig.* 4,) which trunk can be fixed on the ridge of the roof of a house or chamber, by a common carpenter, and a flat sliding cover to slide on at A, to cover the trunk when the box of glasses B is taken away after use. The camera boxes, with the glasses complete, and ready for fixing, are made by Messrs. Jones, of Holborn, and other Opticians. Metallic mirrors have been used instead of glass ones for cameras; they reflect more light, and consequently shew the images brighter, but their liability to tarnish and corrode is an insurmountable objection to their general use.

CAMERAS *Obscuras, construction of portable.* The glasses of a camera obscura are frequently fitted to a portable machine shutting up in the form of a chest, or book, so as to be portable, and easily transported from place to place, and carried about by the artist. The apparatus within is contrived to fold outwards, and form a machine as represented at *fig.* 5, and it is contrived upon the most convenient plan of any hitherto constructed. It is represented as placed together for use. The lid front A, and the slides, one shewn at B, by means of hinges turn up to the height of about two feet from the case C D E, and are fastened together by small brass hooks. The head and sliding box, with glasses F, also fasten on by hooks within. The lens of about 25 inches focus is placed under the true parallel glass mirror, and forms the images on a white sheet of paper, placed in the bottom of the chest. To view the images the face is applied close to a piece under A for that purpose, and to trace the outline, or copy them, the arm at the same time is applied in the cloth sleeve under H. The box F slides on a square tube, and by means of a brass rack and pinion G the lens is adjusted, while the images are viewing, to its proper focal distance from the white paper below. The images formed on the paper have a correct and natural resemblance to the original objects; no inversion takes place, and even names and letters on objects are in their direct order. This camera is converted into an instrument for magnifying perspective prints and drawings, and forms the best possible apparatus for that purpose. The head F G and tube are to be entirely removed, as well as the front A, and cloth C D, and another head with a diagonally-placed mirror and large convex lens, *fig.* 6. substituted, and also hooked on. The prints are to be placed at the bottom of the chest, and as the camera case is open, the print will be illumined either by day light or candle light, as required. The print is viewed by reflection in an horizontal direction, by the eyes being placed before the large convex lens. When the sides and front are unhooked and folded down into the chest, they all lie close, and admit the head to lie under them; and the dimensions of the chest, when thus shut up, do not exceed 2 feet in length, 20 inches in breadth, and 5 inches in depth.

The most portable kind of Camera obscura is that represented at *fig.* 7, and is that most frequently used among artists, on account of its convenient dimensions. The images are reflected on a rough ground plane glass, and are more vivid than those formed on paper, by the Camera above described. It is made of mahogany, and of various dimensions,

fome fo fmall as to be carried in the pocket. The lens at the front A is fixed in the cell, in the front of a fquare draw-out tube, and is of a focus equal to the length of the box when the drawer is half drawn out; and a plain mirror is placed diagonally at the angle of 45°, at the end of the box, as fhewn by the dotted line *a b*, which reflects the rays tranfmitted by the lens up to the upper fide of the plane rough-ground glafs, the rough fide placed above, under the folding darkening cover, and there forming the images of the objects before the lens at A: the ufe of the draw is to adjuft the proper diftance of the lens from the mirror, according to the variable diftances of proximate objects. The images on the rough glafs exhibit a beautiful perfpective picture, alfo the profile of a perfon feated in a room in a ftrong light before the camera, and more particularly if the fun illumine the object; and may be readily traced on the rough furface of the glafs by a black lead pencil, or by what is preferable, red French chalk, and then white paper being gently placed on the glafs, the lines will be taken correctly off. If very thin white paper is merely placed upon the glafs, the images may be difcerned, though faintly, fufficient to afford the means of tracing correctly. The nearer the object or features are to the camera the larger will be the image, and an additional lens of a fhorter focus is fometimes fitted to be fubftituted for the other, when the images of very near objects are wanted. Some artifts who take profiles take out the rough glafs from its cell, invert the camera, and by a ftand fupport it about 10 or 12 inches above the white paper on the table. The image will then invertedly be formed on the paper, and they trace it with a pencil in a correct manner, and with lefs trouble than by the other method. Meffrs. Jones, of Holborn, make an improved camera of this kind, by joining the fide of the camera and drawer in the middle with canvas cloth, as fhewn at the lines B G: the back C turns inward with the mirror, clofe up to the rough glafs, and the front E F above, over the top, fo that the whole camera may fold down into a flat form, and go into a very portable flat leather ftrap cafe, making it the moft portable poffible for perfons travelling. Inclufive of the rough glafs has fometimes been placed a double convex lens to relieve the images, and from more light being thus refracted, the images are fhewn with great beauty and extraordinary brightnefs, even furpaffing the original. They are alfo more vivid when the rough glafs is placed over this lens, though the contours, or outlines, are not fo fharp or diftinct as when the rough glafs is ufed only by itfelf. This improvement was affumed fome years ago, by a perfon of the name of Storer, as a difcovery, and called a *delineator*, but without the leaft pretenfions, it being previoufly well known by the moft eminent opticians, and it was, in the year 1758, noticed by Mr. Hooper, in his Rational Recreations, vol. ii. p. 20. Guyot's Recreations Phyfiques, tom. ii. recr. 35. art. 2. Mr. Harris, in his "Optics," b. ii. § 4. has defcribed a variety of contrivances for converting the portable camera into a fhew box for viewing prints.

Canal

CANAL, *Canalis*, in general, denotes a long, round, hollow inftrument, through which a fluid matter may be conveyed.

In which fenfe, it amounts to the fame with what we otherwife call a pipe, tube, channel, &c. Thus the *canal* of an aqueduct, is the part through which the water paffes; which, in the ancient edifices of this kind, is lined with a coat of maftic of a peculiar compofition.

CANAL, a duct or pipe (as its derivation from the Latin *Cane*, a cane, or reed, feems to imply), in which fenfe it is ufed by anatomifts in defcribing the paffage through which fome of the animal fluids pafs: the term Canal has alfo been applied to denote any piece of water, efpecially if of a confiderable length in proportion to its width, and efpecially fuch as are ftagnant, or have not the fall and natural motion which rivers have. Canals may be either for pleafure or ornament, fuch as are common in the vicinity of palaces and great houfes; or applied to the purpofes of inland navigation. The artificial carriages for conveying ftreams of water for the fupply of cities or other purpofes, as was done by the famous aqueducts of antiquity, and in modern times by the new rivers near London, and others, have fometimes alfo been called Canals.

The importance and utility of canals have been fo long and fo generally acknowledged, that it is hardly neceffary to introduce the fubject with any obfervations to this purpofe. Few perfons have more attentively confidered or better underftood the political and commercial interefts of nations than the late Dr. Smith; and no one could be a more zealous advocate for the extenfion of inland navigation, as an effectual means of improving the country, in which it is encouraged. To this purpofe he obferves, in his "Wealth of Nations" (vol. i. p. 229.), that good roads, canals, and navigable rivers, by diminifhing the expence of carriage, put the remote parts of the country more nearly upon a level with thofe in the neighbourhood of large towns; and on that account they are the greateft of all improvements. They encourage the cultivation of the remote parts, which muft always be the moft extenfive circle of the country. They are advantageous to towns, by breaking down the monopoly of the country in its neighbourhood; and they are advantageous to all parts of the country; for though they introduce fome rival commodities into the old markets, they open many new markets to its produce. "It is not more than 50 years ago," fays he in 1776, when the firft edition of his work was printed, "that fome of the countries in the neighbourhood of London, petitioned the parliament againft the extenfion of the turnpike roads into the remoter counties. Thofe remoter counties, they pretended, from the cheapnefs of labour, would be able to fell their grafs and corn cheaper in the London market than themfelves, and would thereby reduce their rents, and ruin their cultivation. Their rents, however, have rifen, and their cultivation has been improved fince that time." "All canals," fays an intelligent writer on this fubject (See Phillips's General Hiftory of Inland Navigation, Introd.), "may be confidered as fo many roads of a certain kind, on which one horfe will draw as much as 30 horfes on ordinary turnpike roads, or on which one man alone will tranfport as many goods as three men; and 18 horfes ufually do on common roads. The public would be great gainers were they to lay out upon the making of every mile of a canal twenty times as much as they expend upon a mile of turnpike road; but a mile of canal is often made at a lefs expence than the mile of turnpike: confequently there is a great inducement to multiply the number of canals."

The advantages refulting from canals, as they open an eafy and cheap communication between diftant parts of a country, will be ultimately experienced by perfons of various defcriptions: and more efpecially by the manufacturer, the occupier or owner of land, and the merchant. The manufacturer will thus be enabled to collect his materials, his fuel, and the means of fubfiftence, from remote diftricts, with lefs labour and expence; and to convey his goods to a profitable market. As canals multiply, old manufactures revive and flourifh, new ones are eftablifhed, and the adjoining country is rendered populous and productive. To the occupier of land, canals are ufeful in a variety of ways. In fome cafes, they ferve the purpofes of draining and of irrigation; in others, they furnifh manure at a cheap rate; and they facilitate the conveyance of the produce to places where it may be difpofed of to the greateft advantage. The landowner muft of courfe be benefited, by the increafing value and advanced rent of his eftate, in confequence of the improvement it receives from the induftry of the occupier, excited and encouraged by an immediate recompence. The wholefale trader and merchant are likewife enabled to extend their commerce by means of canals; as they can thus export greater quantities and varieties of goods from places remote from the fea, and eafily fupply a wider extent of inland coun-

country with the commodities that are imported from foreign nations. Nor are they merely the means of extending and increasing foreign commerce, but they serve also to create and augment an internal trade, which, with all the advantages attendant on foreign commerce, may probably far exceed it in extent, value, and importance. We might add, that an inland communication between parts of a country, at a great distance from one another, contribute to the security, as well as to the extension of commerce, in the boisterous months of winter, and in times of war, when the navigation of the seas would be attended with danger. "Were we to make the supposition of two states," says Mr. Phillips (ubi suprà), "the one having all its cities, towns, and villages upon navigable rivers and canals that have an easy communication with each other; the other possessing the common conveyance of land-carriage; and supposing, at the same time, both states to be equal as to soil, climate, and industry; commodities and manufactures, in the former state, might be exported 30 *per cent.* cheaper than in the latter; or, in other words, the first state would be a third richer and more affluent than the second." Should it be objected, that navigable canals waste or occupy too great a portion of land in the countries through which they pass, the objection may be obviated by the consideration, that one mile of a canal, 14 yards wide, takes up little more than five acres of land.

If we advert to fact, and consult the records of history with regard to the state of different nations, we shall find, that civilization and commerce have very much depended on the facility with which the inhabitants of remote districts have maintained intercourse with one another, as well as with distant countries. As the ocean serves to connect distant countries, navigable rivers and canals unite the different provinces and districts of the same country; and as navigation, by means of the ocean, produces an intercourse and mutual exchange of productions between different kingdoms, inland navigation, in like manner, facilitates a communication between different parts of the same kingdom, and consequently promotes trade and industry. In North America, the plantations have constantly followed either the sea-coast or the banks of the navigable rivers, and have scarcely any where extended themselves to any considerable distance from the one or the other. The nations that appear to have been first civilized, were those that dwelt round the coast of the Mediterranean sea, which, from a variety of circumstances, was extremely favourable to the early navigation of the world. Of all the countries on the coast of the Mediterranean, Egypt seems to have been the first, in which either agriculture or manufactures were cultivated and improved to any considerable degree. Upper Egypt extends itself nowhere above a few miles from the Nile, and in Lower Egypt that great river breaks itself into many different canals, which, aided by a small degree of art, seem to have afforded a communication by water-carriage, not only between all the large towns, but between all the considerable villages, and even to many farm-houses in the country; nearly in the same manner as the Rhine and the Maese do in Holland at present. The extent or facility of this inland navigation was probably one of the principal causes of the early improvement of Egypt. The improvement in agriculture and manufactures seems likewise to have been of very great antiquity in the provinces of Bengal in the East Indies, and in some of the eastern provinces of China. In Bengal, the Ganges and several other large rivers form a great number of navigable canals, in the same manner as the Nile does in Egypt. The case is the same in the eastern provinces of China, where several large rivers form, by their different branches, a multitude of canals, and by communicating with one another afford an inland navigation much more extensive than that either of the Nile or the Ganges, or perhaps of both of them united. It is remarkable, however, that neither the ancient Egyptians, nor the Indians, nor the Chinese, encouraged foreign commerce; but they all seem to have derived their extraordinary opulence from this inland navigation. On the other hand, those nations that have been destitute of the means of inland navigation, either by rivers or canals, have remained from one age to the other in the same barbarous and uncivilized state. This observation is exemplified in the state of all the inland parts of Africa, and of that part of Asia which lies at any considerable distance north of the Euxine and Caspian sea, the ancient Scythia, and the modern Tartary and Siberia. The commerce that may be carried on by means of a river, which does not break itself into any great number of branches or canals, and which runs into another territory before it reaches the sea, can never be very considerable; because it is always in the power of the nation who possesses that other territory to obstruct the communication between the upper country and the sea. Thus the navigation of the Danube is of very little use to the different states of Bavaria, Austria, and Hungary, in comparison of what it would be if any of them possessed the whole of its course till it falls into the Black Sea. To these general observations, we shall subjoin a brief account of the principal canals that have been formed among the nations of antiquity, and among foreign nations in later times; reserving the principal part of this article for an enumeration of the canals of our own country, and for an illustration of the principles on which they are constructed, the regulations to which they are subject, and the various uses to which they are applied.

In the history of ancient nations we discover various traces of canals, formed for military, agricultural, commercial, or other purposes. The "fossiones Philistinæ" of Pliny (l. iii. c. 16.), which were large canals at the mouth of the Eridanus in Liguria, are ascribed by Mr. Bryant to the Canaanites, and particularly to the Caphtorim, who at a remote period migrated from Philistim; and hence these outlets of the river were named "Philistinæ." We learn from Herodotus (l. i. c. 174.) that the Cnidians, a people of Caria in Asia Minor, formed a design of digging a channel through the isthmus which joined their territory to the continent; but they relinquished the undertaking, because they were interdicted by an oracle. Strabo informs us (l. ix. p. 406, &c.) that canals and pits were dug in Bœotia, at a very remote period of antiquity, for drawing off the water of the lake Copais, which would otherwise have overflowed the whole country. This lake near the sea terminates in three bays, which advance to the foot of mount Ptous, situate between the sea and the lake. From the bottom of each of these bays numerous canals were made to diverge and traverse the mountain through its whole breadth, some of which were more than a league in length, and others of a much greater extent. For the purpose of excavating or of cleansing them, very deep wells had been sunk at stated distances on the mountain. The labour of forming and the expence of maintaining these canals must have been immense. They have since been almost wholly neglected, so that most of them are choaked up, and the lake seems to be gaining on the plain. The inhabitants of Babylonia or Chaldæa guarded against the detrimental inundations of the Tigris and Euphrates by a great number of artificial rivers and canals, which served to distribute waters, to benefit the country

in general, and to effect an easy communication and intercourse between the occupiers of different parts of the country. The Euphrates, according to Ptolemy (l. v. c. 17.), above Babylon, near a town in Mesopotamia, called Sipphara, divides itself into two branches, one running to Babylon, and the other to Seleucia, where it falls into the Tigris. The latter, says Pliny (l. vi. c. 26.), was partly artificial; and he places Seleucia at the confluence of the Tigris and Euphrates, adding that the Euphrates was conveyed to it by a canal. Prideaux, (Conn. b. ii. part i. p. 103.) on his authority, supposes that branch to have been artificial, and ascribes it to Nebuchadnezzar. Between these two branches an artificial canal was cut from the Euphrates, above Babylon, to the Tigris at Apamea, 60 miles below Seleucia. This canal, which was large and navigable, was called *Naarmalcha*, which see. From the Naarmalcha the emperors Trajan and Severus, in their wars with the Parthians, dug a new canal to the Tigris, near Coche on the west, and Ctesiphon on the east side of that river. At the distance of 800 furlongs from Babylon, to the south was another canal, called by Arrian (Exped. Alex. l. vii.) Pallacopas, and by Appian (Bell. Civil. l. ii.) Pallacotta, derived from the branch of the Euphrates that passed through Babylon and conveyed water to certain lakes or marshes in Chaldæa. On this canal, or river, as Arrian calls it, Alexander sailed from the Euphrates to these lakes. Strabo (l. xvi.) describes the course of this canal, without naming it. But it is impossible to trace out, with accuracy, these and the other numerous branches and canals which watered the ancient country of *Babylon*, which see. Many of those that were formerly considerable are now lost; and others have been formed since, that did not exist in ancient times; for a country so much watered, so low in situation, and so subject to the violence of extraordinary inundations from the two large rivers, the Tigris and Euphrates, and so neglected as it has been for several ages, must have often and very considerably changed its face since the time of Ptolemy; and it is almost impossible to describe it such as it was while it continued to be the seat of empire, when the inhabitants were rich enough to take care of its numerous banks, and to keep them in repair. See BABYLONIA.

Both the Greeks and Romans proposed to make a canal across the isthmus of Corinth, which joins the Morea and Achaia, and thus to make a navigable passage by the Ionian sea into the Archipelago. Demetrius Poliorcetes, Julius Cæsar, Nero, and Caligula renewed the attempt, but without success. Plin. l. iv. c. 4. After the death of Alexander the Great, Seleucus Nicanor attempted to make a canal between the Euxine and Caspian seas, but his undertaking proved abortive. Travellers, however, assert that traces of very deep vallies are to be seen, through which the canal is said to have passed. Selim II. and Peter the Great, renewed the attempt, but they were prevented from succeeding, not so much by the impracticability of the scheme as by other collateral circumstances. The Romans, more intent on conquests than on commerce and the arts, afford us few instances of canals for internal navigation. We find, however, that Drusus, under the emperor Augustus, having conceived the design of marching into Germany without harassing his troops by a long and difficult march, facilitated the execution of it by making a canal that communicates from the Rhine with the Issel, extending from the village of Iseloort to Doesbourg. This canal received a great part of the waters of the right branch of the Rhine, which became by that means much less considerable. At the same time he opened a third mouth from that river into the sea, mentioned by Pliny under the name of "Flevum Ostium." But the face of the country has been much altered from that time Lucius Verus who commanded the Roman army in Gaul under Nero, attempted to make a canal between the Moselle and the Rhine. Corbulo under Claudius employed his soldiers in digging a canal between the Rhine and the Maese, though an interval of about 23 miles, in order to preserve the country from inundations, and to serve as a drain, in case of any extraordinary overflowings of the sea. Cluverius and Cellarius suppose this to be the canal that begins at Leyden, passes by Delft, continues on to Maesland, and joins the Maese at the village of Sluys. Claudius also employed 30,000 men for about 12 years in digging a canal through a mountain for draining the lake Fucinus (now Celano) into the river Liris; and in 1789 this canal was begun to be cleansed to the great relief of the neighbouring country, which was inundated by its obstruction. The Romans, during their residence in this country, made a canal between the Nyne, a little below Peterborough, and the Witham, 3 miles below Lincoln, called by the modern inhabitants "Caerdike," which is now almost wholly filled up. It was almost 40 miles long, and, as far as we may judge from the ruins, very broad and deep. Some have supposed it to be a Danish work. J. Morton supposes it to have been made under the emperor Domitian. Urns and medals have been discovered on the banks of this canal, which seem to confirm that opinion. Morton's Hist. Northamptonshire, ch. 10. Charlemagne, at a later period, formed a design of joining the Rhine and the Danube, and of thus making a communication between the ocean and the Black sea, by a canal extending from the river Almutz, which discharges itself into the Danube, to the Reditz, which falls into the Maine; and the Maine joins the Rhine near Mayence. In the execution of this design he employed a great number of workmen, but he was prevented from completing it by a variety of obstructions which occurred. Of all the countries to which ancient history directs our attention, Egypt was the most distinguished by its numerous canals, which, according to Savary, amounted to 80, several of which are 20, 30, and 40 leagues in length. These served to receive and distribute the waters of the Nile, at the time of its inundation. Most of these are neglected, and, consequently, one-half of Egypt deprived of the means of its cultivation. The canals which convey the water to Cairo, to the province of Faioum, and to Alexandria, seemed to have engaged the chief attention of government. "An officer," says baron De Tott (Memoirs, vol. ii. p. 21, &c. Eng. ed.) "is appointed to watch this last, and hinder the Arabs of Bachria, who receive the superfluous waters of this canal, from turning them off before Alexandria be provided, or opening it before the time fixed, which would hinder the increase of the Nile. That which conveys the waters into Faioum is watched in like manner, and cannot be opened before that of Cairo, which is called the canal of Trajan." But the principal of these works was the Grand Canal, by which a communication was made between the Nile and the Red sea. This was begun, according to Herodotus (lib. ii. p. 181, &c. ed. Wesselingii.) by Necos, the son of Psammitichus, who desisted from the attempt on an answer from the oracle, after having lost 120,000 men in the enterprise. Strabo (lib. xvii. p. 1157. ed. Casaubon.) ascribes the commencement of it to Sesostris, before the Trojan war. It was resumed and carried on by Darius, son of Hystaspes, who relinquished the work on the representation made to him by unskilful engineers, that the Red sea being higher than the land of Egypt, would overwhelm and drown the whole country. Diodorus Siculus (lib. i. p. 39. ed. Wesselingii.) gives the following account of this canal. "A canal of communication has been cut, which passes from the gulf of Pelusium to the Red Sea. It was begun by

Necos, the fon of Pfammitichus, and continued by Darius king of Perfia; but left imperfect in confequence of the advice of fome perfons who afferted that it would lay Egypt under water, becaufe the land was below the level of the Red fea. Ptolemy II., however, finifhed the undertaking, and conftructed, in the moft convenient part of the canal, a dam, or fluice, ingenioufly contrived, which opened to give paffage, and immediately clofed again. Hence the river which difcharges itfelf into the fea, near the city of Arfinoe, has received the name of Ptolemy." From this paffage, fays baron De Tott, it is plain, that the fluices ftill exifted in the time of Diodorus. The entrance of the canal near Suez yet remains, and might eafily be rendered navigable, without employing fluices or locks, as the difference of the level is very fmall, and without endangering Egypt with inundations. This part of the ifthmus, fays the baron, affords land very favourable for fuch an excavation, through the fmall interval of 12 leagues, which feparates the Arabian gulf from the arm of the Nile which approaches it, and afterwards falls into the Mediterranean at Tineh. Strabo adds (ubi fupra) that this canal was afterwards cleanfed by Trajan. Its width, being 100 cubits, of 22 inches to a cubit, was fufficient for admitting the paffage of two galleys abreaft; and its depth was fuch as to bear the largeft veffels. Pliny, in his account of this canal, (lib. vi. cap. 29.), ftates its breadth at 100 feet, its depth at 40, and its length to the bitter fountains (near Arfinoe) at 37 miles. By means of this canal, the valuable commodities of India, Perfia, Arabia, and the kingdoms on the coaft of Africa, which were brought by fhipping to the Red fea, were conveyed to the Nile; and thence diftributed by the Mediterranean not only to Greece and Rome, but to all the furrounding nations, until the Portuguefe difcovered a paffage to India by the Cape of Good Hope. It did not, however, long ferve the ufeful purpofes of commerce, which were at firft expected. Merchants were diffatisfied with the delay occafioned by going to the very bottom of the gulf, and afterwards with the inland navigation of the canal, and that of the Nile, to Alexandria. They found it much more expeditious to unload at Berenice, near the coaft of the Red fea (fee Berenice): and after three days' journey, to fend their merchandife directly down to Alexandria. Accordingly, this canal was difufed, and goods were conveyed from Berenice to the Nile by land; a mode of conveyance occafionally ufed at this day. Strabo and others have afferted, that this canal was again opened about the year 635, by Amru, governor or prefect of Egypt, under the caliph Omar, for the conveyance of the corn of Egypt to Arabia, which was then grievoufly diftreffed by a famine. Elmacin, or Al Makin, fays, that a new canal was opened for this purpofe, and called by Amru the river of the emperor of the faithful; but it has been more generally fuppofed, that he only renewed the ancient canal, the navigation of which, towards the decline of the Roman empire, had been much neglected. The authors of the Modern Univerfal Hiftory (vol. i. p. 333.), difcredit the relation of Elmacin and Eutychius; and allege that there never was any paffage for veffels dug between the towns of Al Foftat, on the eaftern bank of the Nile, and Al Kolzom or Colzum on the Red fea. The river, or rivulet, denominated by them the river of the emperor of the faithful, fay thefe authors, was undoubtedly no other than the Amnis Trajanus of Ptolemy, or the Khalig, which annually fupplies the city of Cairo, as well as the neighbouring country with water. For the prefent ftate of this canal, fee Cairo. They fuppofe, therefore, that, on the occafion now referred to, the caliph Omar ordered Amru to make the Khalig more navigable, by clearing it of the gravel or fand with which it was then choaked up; and that, for this reafon, it received the name of the river of the emperor of the faithful. Elmacin farther informs us, that the Alexandrian canal was ftopped again, at the end next the Red fea, by the caliph Abu Jaafar, or Almanfor, in the year of the Hegira 150, A.D. 767. Some traces of this canal are ftill fubfifting; and M. Boutier, in 1703, difcovered that end of it, which rifes out of the moft eafterly branch of the Nile. Hift. Acad. Sc. for 1703, p. 110, &c.

The canal of Alexandria, cut from the Nile to this city by Ptolemy, during the inundation of the Nile, receives its water at Latf, oppofite to Fouah, and has three bridges over it, of modern conftruction. Near the former, by the fea-fide, is the entrance of the fubterraneous aqueduct, that carries a fupply of water for the Alexandrians into the cifterns, the arches of which fupported the whole extent of the ancient city, but they are now incapable of being traced out. The mouth of this aqueduct is now blocked up; but when the water of the canal had arrived to a certain height, in confequence of the rife of the river, the principal magiftrates of the city went in great ceremony to break down the dam. When the cifterns were full, it was again built up, and the water of the canal continued to fall into the fea at the old port. It was by this eafy communication that merchandife was formerly conveyed through Egypt. The dangerous paffage of the mouth of the Nile was thus avoided, as well as the perils of the fea. But befide furnifhing the city with water, and facilitating its commerce, this canal, which paffed along the upper part of the cultivated lands, on the left band of the Nile, contributed very much to their fertility. In procefs of time it was fhamefully neglected. However, it was cleanfed by order of Bonaparte, in his irruption into Egypt, as far as Rhamania. See Alexandria.

Egypt is interfected in various directions by many other canals. Several of them iffue from that arm of the Nile which runs to Damietta, and contribute to fertilize the province of Sharkia, which, making part of the ifthmus of Suez, is the moft confiderable of Egypt, and the moft capable of a great increafe of cultivation. Others run through the Delta, and of thefe, fays baron De Tott, many are navigable. The canal of Menouf communicates with the two branches of the Nile, 10 leagues below the angular point, called the "Belly of the cow." See Menouf. The canal of Bahira proceeded from the lake Mareotis, near Alexandria, and having fent off branches which joined the weftern branch of the Nile at Efhlim, Shabur, and Nadir, paffed on to Upper Egypt. The other principal canals of Egypt will be mentioned in connection with the towns or diftricts to which they belong.

There is no country on the face of the globe that abounds more with canals and navigable rivers than China: to which article we fhall refer an account of its inland navigation. Hindooftan likewife furnifhes inftances at a remote period of the acknowledged importance and utility of canals. As the country between Delhi and the Panjab was fcantily fupplied with water, the emperor Ferofe III., who died in 1388, undertook, fays major Rennell (Memoir, p. 71.), the noble, as well as ufeful, tafk of fupplying it better, and at the fame time of applying the water, fo furnifhed, to the purpofes of navigation.

The immediate object of the canals, projected and executed by Ferofe, for an account of which we refer to Rennell (ubi fupra) feems to have been the junction of the Setlege and Jumnah rivers, through an interval of 240 geographical miles, and remotely that of the Indus and Ganges. If this grand defign of Ferofe had been completed, it muft have ranked with the greateft works of this kind; "for we

should then have seen two capital rivers, which traverse a large part of Southern Asia, which enter the sea at the distance of 1500 British miles asunder, and which stretch out their arms, as it were, to meet each other, united by art: and those by nature to a third; so as to form an uninterrupted inland navigation from the frontiers of China to those of Persia." The country of Bengal is so intersected in various directions by the natural canals of the Ganges and Burrampooter rivers, together with their numerous branches, as to form the most complete and easy navigation that can be conceived: and it is supposed, that this inland navigation furnishes constant employment for 30,000 boatmen, who are employed in conveying by water through the kingdom of Bengal and its dependencies, all the salt and a large proportion of the food consumed by 10,000.000 people, and in transporting commercial exports and imports, probably to the amount of 2,000,000l. sterling per annum.

The improvement of inland navigation engaged but little attention in Russia before the reign of Peter the Great. With him, after his return from Holland, where he had observed its useful effects, the construction of canals became a principal object. Of those projected and hastily executed by him, we may mention that of Cronstadt, that of Ladoga, that of Vishnei-Voloshok, and that for forming a communication between Moscow and the Don. For an account of the canal of Cronstadt, which was left unfinished by czar Peter, see CRONSTADT. The Ladoga canal was begun in 1718 by his order, and finished during the reign of the empress Anne. It was carried out first only as far as the Kabona, a rivulet which enters the lake to the east of Schlusselburgh; but now reaches, without interruption, from the Volkof to the Neva. The length is 67½ miles, and its breadth 70 feet; the mean depth of water in summer is seven, and in spring ten feet; it is supplied by the Volkof and eight rivulets. The barks enter through the sluices of the Volkof, and go out through those of Schlusselburg. In 1778, four thousand nine hundred and twenty seven vessels passed through this canal. A scheme has been projected, and in part executed, for uniting the White Sea and the Baltic, and thus improving the commerce between Archangel and Petersburgh, by forming a communication between the Ladoga and Beilo-Ozero to the Duna. The canal of Vishnei-Voloshok, forms a communication by water between Astracan and Petersburgh, or between the Caspian and the Baltic. This canal was begun and completed under Peter the Great; but it has been considerably improved by the empress Catharine, so that vessels reach Petersburgh in half the time which they formerly employed. In order to form an idea of the course of this inland navigation, a map of Russia should be consulted; and it will be seen, that the river Shlina forms the lake Mastino, which gives rise to the Masta; this, after a course of 234 miles falls into the lake Ilmen, from which issues the Volkof; and this, running 130 miles to the lake Ladoga, supplies the Neva; so that, in effect, the Shlina, the Masta, the Volkof, and the Neva, may be considered as the same river flowing into and through different lakes. By uniting, therefore, the Shlina, which communicates with the Baltic, with the Tvertza, which flows by the Volga into the Caspian, the canal of Vishnei-Voloshok completes the communication between these two seas. In autumn the navigation from Vishnei-Voloshok to Petersburgh is performed in little more than a month; in summer in three weeks. In one year 3485 barks have passed through this canal.

The grand project of uniting the Caspian and the Baltic with the Black Sea, by the junction of the Don and Volga, was planned by Peter the Great. These two rivers approach each other within the distance of 40 miles in the province of Astracan; and two rivulets, the Ilosla which falls into the Don, and the Camashinska falling into the Volga, are separated only by an interval of five miles. If these rivulets could be made navigable, and united by a canal, the Black Sea would be joined with the Caspian and Baltic. Repeated attempts have been made for this purpose, but they have hitherto failed. However, as the Volga and the Don are but 40 miles distant, and land carriage in this country is very cheap and easy, the advantages resulting from the projected canal would be scarcely equivalent to the expence of forming it. In 1802, a beautiful chart was published, exhibiting a view of all the canals in Russia, that have been formed between the White and Black Sea, and between the Baltic and the Caspian. The inland navigation is already carried through such an extent in Russia, that it is possible to convey goods by water 4472 miles from the frontiers of China to Petersburgh, with an interruption only of about 60 miles; and from Astracan through a tract of 1434 miles. Cox's Travels in Poland, Russia, &c. vol. iii. Tooke's view of the Russian Empire, vol. i.

The first sovereign of Sweden, who duly appreciated the utility of inland navigation, was Gustavus Vasa. Having made Lodese (now Gotheborg) a staple-town of trade, he conceived hopes, that in order to prevent the merchant-ships bound to Sweden from being obliged to sail through the Sound, the merchandize might, at some future period, be transported from thence to Stockholm, by means of the Wenner, Hielmar, and Mæler, when the rivers and lakes uniting with them should be rendered navigable. Eric XIV. desirous of executing his father's plans, directed a survey to be made of the waters communicating with those lakes, and plans to be formed for joining them by artificial canals. But the turbulence and misfortunes of his reign frustrated the accomplishment of his designs. The same object was kept in view by succeeding sovereigns. Charles IX. promoted it by the Carlsgraf canal, and Charles XI. by that of Arboga. Gustavus Adolphus wished to encourage the design, but could not find persons competently qualified to execute it: and Charles XI. was discouraged by the report of Dutch engineers, who declared it impracticable. Charles XII. however, approved the proposal of the celebrated engineer, Polhem, for rendering the cataracts of Trolhætta navigable, and for opening a communication, not only between Gotheborg and Stockholm, but also with the Wenner, the Vetter, and Nordkioping, sufficient for the passage of large vessels. The execution of this plan was immediately begun by his order, and, after his death, revived by Adolphus Frederic. It comprehended three principal parts; viz. the junction of the Mæler and the Hielmar, of the Hielmar and Wenner, and of the Wenner with the German Ocean. The two lakes of the Mæler and Hielmar are united by the Ulvison, and the canal of Arboga. This canal (see ARBOGA) is, for the most part, of sufficient breadth to receive two barks a-breast, and its lowest depth is eight Swedish feet. It is chiefly supplied with water from the lake Hielmar, which is 80 feet higher than its level; and this fall is broken by eight sluices. With a view of joining the Hielmar and Wenner, many schemes were proposed, but difficulties occurred which prevented the completion of them. The junction of the Wenner with the German Ocean has been attempted by the Carlsgraf canal, the canal of Trolhætta, and the sluices of Akerstræm and Edet. The Carlsgraf canal, so called from Charles IX. who commenced it, connects the Wenner with that part of the Gotha, where it is first navigable. In 1758 a new sluice to supply the place of that of Polhem, carried away by the water, and of that

called Teſſin, found inſufficient, was completed; and denominated the ſluice of Guſtavus. This ſuperb work is a cut of 400 feet, partly perforated through the ſolid rocks, and conſiſting of two locks, each 200 feet long, and 36 broad; the ſides being ſtrongly faced with brick and ſtone. The greateſt depth of water is 13, and the loweſt ſix feet. This canal is commonly navigated by veſſels of 80 tons burden. From the end of this canal to the village of Trolhætta, including an interval of five miles, the navigation of the Gotha is uninterrupted; but when it burſts at once into the cataracts of Trolhætta, called the "gulfs of hell," all farther navigation becomes impracticable through a ſpace of about two miles. Here it is divided into four principal cataracts, ſeparated by whirlpools and eddies, and deſcending through a perpendicular height of 100 feet. Nevertheleſs, an attempt has been made to form a canal through theſe cataracts. The firſt attempt, after much labour and expence, failed; and another plan was adopted. The length of the canal was to be 4700 feet, its breadth 36, and its depth in ſome parts above 50; and it was to conſiſt of nine ſluices; but the whole of the cut was to be excavated through a bed of red granite; and though it ſhould not be condemned as impracticable, the difficulties attending it appear to be almoſt inſuperable. After all, it has been doubted, whether the enormous expence attending the execution of it will be compenſated by the advantages reſulting from its completion. Guſtavus III., ſoon after his acceſſion, viſited the works, and ordered all of them to be ſuſpended, except the ſluices of Guſtavus and Aker. But, in order to facilitate the conveyance of merchandiſe from the diſtricts bordering on the Wenner to Gotheborg, a wooden road has been conſtructed on the ſide of the river, from the beginning to the end of the cataracts. About a mile below the cataracts, the courſe of the Gotha is again interrupted by a fall, called Akerſtræm; and here a canal has been made through a rock, 182 feet long, including the ſluice, 26 deep, and 36 broad. From Akerſtræm the river is clear to Gotheborg, excepting at Edet, where it is intercepted by a bed of rocks. On one ſide of theſe rocks another cut has been made, 600 feet long, 20 deep, and 18 broad. The iron and other merchandiſe are now tranſported acroſs the lake to Wennerſborg, through the Carlſgraf canal, and down the river Gotha to Trolhætta. At the cataracts they are unloaded, carried over the wooden road two miles to the end of the falls, again embarked, and paſſing through the Akerſtræm and Edet ſluices, arrive without further impediment at Gotheborg. Coxe's Travels, vol. iv.

The principal canal of Denmark is that of Kiel. This canal was deſigned to complete the inland navigation, which, for the purpoſe of facilitating the communication between the Baltic and the German Ocean, is formed acroſs the duchy of Holſtein, and it unites with the river Eyder, which paſſes by Rendſburgh, and falls into the German Ocean at Tonningen. It begins about three miles N. of Kiel, at the mouth of the river Lewenſawe, which heretofore ſeparated Holſtein from Sleſwic, and will become a new boundary between theſe two duchies. The diſtance from its beginning to the eaſt ſluice at Rendſburgh is 27 Engliſh miles; but as the Eyder is navigable about 6¾ miles above Rendſburgh, the cut neceſſary for completing the communication between the two ſeas is only 20¼ miles. It was begun in 1777, and was opened in 1785. The perpendicular fall towards the Baltic is 25 feet ſix inches; that towards the ocean 23; and the veſſels will be raiſed or let down by means of ſix ſluices. The breadth of the cut is 100 feet at the top, and 54 at the bottom; the ſluices are 27 feet broad and 100 feet long, and the loweſt depth of water is 10 feet. Merchantmen of about 120 tons burden will be able to navigate this canal. The utility of this important undertaking is indiſputable. At preſent, even the ſmalleſt veſſels, trading from any part of the Daniſh dominions in the Baltic to the Northern Sea, muſt make a circuit round the extremity of Jutland, and are liable to be detained by contrary winds. This navigation is ſo tedious, that goods ſhipped at Copenhagen for Hamburgh are not unuſually ſent by ſea only to Lubec, and from thence by land. The object, ſays Mr. Coxe, of thoſe who planned this canal, was to draw by Kiel into the Baltic, the commerce of Bremen, Hanover, and Weſtphalia, which is now carried down the Weſer, and by Gluckſtadt upon the Elbe, to Hamburgh and Lubec; and to facilitate the tranſport of merchandiſe from Holland and the North Sea to the ports of the Baltic. But the difficult navigation of the Eyder between Rendſburgh and Tonningen, occaſioned by numerous ſhoals of ſhifting ſands, will prevent the complete ſucceſs of this canal. Ships ſailing from the Baltic to Engliſh or French ports, will without doubt prefer the navigation round the Cattegate, with all its dangers and difficulties. The trade of Kiel, however, will at all events be greatly increaſed by this canal; but the principal depoſitory of the merchandiſe will be at Rendſburgh. Coxe's Travels, vol. v.

The canals of Holland and Flanders are innumerable; and they ſerve the purpoſe of our public roads, ſo that the inhabitants may travel by means of them in their trehſchuyts and barges, and convey commodities for conſumption or exportation, from one part of the country to another, as occaſion requires. An inhabitant of Rotterdam, it is ſaid, may, by means of theſe canals, breakfaſt at Delft or the Hague, dine at Leyden, and ſup at Amſterdam, or return home again before night. By them alſo a prodigious inland trade is carried on between Holland, France, Flanders, and Germany. When the canals are frozen over, they travel on them with ſkaits, and perform long journies in a very ſhort time, while heavy burdens are conveyed in carts and ſledges, which are then as much uſed on the canals as in our ſtreets. The profits which have accrued from theſe canals have been immenſe; and their amount almoſt exceeds belief. It is ſaid, that they have yielded more than 250,000l. for about 40 miles of inland navigation. The canals of Holland are generally 60 feet wide, and ſix deep, and are kept cleanſed; the mud, as manure, being very profitable. They are generally level, and need no locks; and they are commonly elevated above the country for the purpoſe of carrying off the waters, which in winter inundates the land. In the province of Delftland, not more than 60 miles long, 200 wind-mills are employed in ſpring to raiſe the water into the canals. On the dams or banks by which they are bordered, and which are kept in repair at a very conſiderable expence, depends the ſecurity of the country from inundation. The canals of Flanders, ever ſince their trade has declined, and the cities erected on their banks have decayed, have been very much neglected. They indicate, however, the former flouriſhing and proſperous ſtate of the country. So early as the 12th century, large canals were cut; and they anſwered the purpoſe of inland commerce as well as of draining the land. The ſpacious canal of Bruſſels, begun in 1531, and completed in 1560, extends from this city to the Scheldt, which opens a communication with Holland, and by the canals of Flanders with the ocean. The canals of the other Dutch and Flemiſh towns will be mentioned under their reſpective articles.

France has from a very diſtant period exerciſed its ingenuity and activity in the conſtruction of canals for inland navigation. We muſt content ourſelves with a curſory

mention of some of the principal. The canal of Briare, called also the canal of Burgundy, was begun under Henry IV. and finished in the reign of Louis XIII. It opens a communication between the Loire and the Seine, and then between Paris and the western provinces. Commencing at the Loire near Briare, it passes to Montargis, joins the canal of Orleans, which was begun in 1675, and has 20 sluices, and falls into the Seine near Fontainbleau. It has 42 locks and sluices; and is of great use in inland commerce. The canal of Picardy connects the river Somme with the Oise; and beginning at St. Quintin, joins the Oise, and affords a ready conveyance to Paris for the grain of Picardy, the sea-coal, wood, butter, copper, and spices from the northern provinces of the kingdom, and from Holland. The most considerable work of this kind is the canal of Languedoc, called the canal of the two seas, which forms a junction between the Ocean and the Mediterranean. It was first projected under Francis I., but begun in 1666, and finished in 1681, under Louis XIV., during the ministry of Colbert, and by the skill of Riquet, the engineer. It established a ready communication between the two fertile provinces of Guienne and Languedoc, and extends from Cattee in the bay of Languedoc, to the Garonne below Thoulose, being provided at proper intervals with 114 locks and sluices. In some places it is conveyed by aqueducts over bridges, under which other rivers pursue their course. Near the town of Beziers, it was conveyed under a mountain by a tunnel, then thought singular and extraordinary, but now common, 720 feet in length and lined with free stone. At St. Ferriol it derives a supply of water from a reservoir containing 595 acres. Its breadth is 144 feet, including towing-paths; it is six feet deep, and its length 64 French leagues, or about 180 miles. The expence of its construction was about 540,000l., defrayed partly by the king, and partly by the province of Languedoc. On the reduction of the army and navy in 1782, after the conclusion of the American war, the disbanded soldiers and seamen were employed in the construction of three navigable canals; viz. one, called the canal of Dehune, extending from Chalon-sur-Saone to the town of Dijoin on the Loire, through an interval of 21 leagues, and forming a junction with the Saone and the Rhone: a second, called the canal of Burgundy, reaching from St. Jeane-de-l'Aune to the village of Roch, between St. Florentine and Joisny, through a space of 52 leagues, and opening a communication between the Saone, the Rhine, the Yonne, and the Seine; and a third, called the canal of Neuf-Brissac, which commences at the village of St. Symphorin, on the Saone, and passing the city of Besançon, is continued below Strasburgh, forming a junction of the Saone with the Rhone, and of the Ill with the Rhine. By these canals goods may be conveyed at a cheap rate from Marseilles, the Mediterranean, Italy, and Switzerland, to the bay of Biscay and the Ocean, and also to Holland and Germany, as well as to Flanders and the Austrian Netherlands; and during any future war with England, France will be able to supply, by these canals, her dock-yards at Marseilles and Toulon, and also her grand arsenal and dock-yards at Brest and Rochfort, with all sorts of commodities from the Baltic, without hazarding a voyage by sea. It would be endless to enumerate all the canals, projected or actually executed in France, and forming an easy intercourse between the different districts of this extensive country. A survey has lately, in 1802, been made of the little river Buzeg or Bureg, with a view of its being brought to Paris in the same manner as the New River is brought to London, and of being laid into the streets and houses by pipes, fire-plugs, and engines, for the purpose of cleansing the streets, as well as accommodating the houses. Phillips's Inland Navigation, p. 75. 8vo.

Spain has not been altogether inattentive to the improvements likely to result from inland navigation. At former periods it has been often proposed to dig a canal through the isthmus of Darien, from Panama to Nombre de Dios, and thus to make a ready communication between the Atlantic and the South Seas, and to open a straight passage to China and the East Indies. The project, however, has been considered as chimerical, and treated with ridicule. The improvements meditated at home are of much greater importance: but though the inland navigations of Spain have been commenced upon principles both of grandeur and utility, they have been suffered to languish through the want of resources, and the tardy measures of the court. The great canal of Arragon afforded, in 1785, some hopes; but it seems to remain in an imperfect state. Two branches, however, are completed: those of Taustre, and the imperial canal, both of which begin at Navarre and terminate in the river Ebro, and they have already proved sources of industry to all the districts through which they flow, and rendered the fields fertile. One of these canals is conducted over the valley of Riojalon, by an aqueduct 710 fathoms in length, and 17 feet thick at the bason. Another canal called the canal of Castile was projected to begin at Segovia, about 40 miles N. of Madrid, and to extend to the bay of Biscay, through a distance of 140 leagues. This canal is 56 feet wide at the top, 20 feet at the bottom, and nine feet deep, but the completion of it will require many years. The canal of Guadarama was planned in 1784, and being conducted with spirit, is probably now completed. It was to commence at the foot of the mountains of Guadarama, near the Escurial, and to proceed to join the Tagus, afterwards the Guadiana, and terminate at the Guadalquivir, above Anduxar. Another canal was also begun to join the river Manzanares to the Tagus; but the work was suspended. The canal of Murcia was found, after its commencement, to be impracticable. Phillips's Inland Navigation, p. 75, &c.

The Americans possess a country capable of great and easy improvement by internal navigation. To this object they are not inattentive. For an account of their projects and actual progress in this business, we must refer to Phillips's Inland Navigation, p. 571, &c., or to the Journals of Mr. Elkanah Watson.

CANALS, *the British*; from the great influence which they appear to have had, among other causes, during the last half century, in promoting the rapid increase of our commercial greatness as a nation, have induced us to lay before our readers a very full account, not only of the present existing canals, but of the principles and practice of canal making, in the united kingdoms. As very few of the English, Welch, Scotch, and Irish rivers, are of sufficient magnitude, and free from shoals, to answer the purposes of navigation far into the country from the sea, without the aid of art, conducted upon similar principles to those used in canal-making; and as nearly all our canals connect with the navigable rivers, and act in some measure, as extensions of them further into the country, we have found it expedient to include under this article, whatever we have been able to collect on the subject of the *Inland Navigation of the United Kingdom*.

That the navigation of our rivers, by ships or smaller vessels has long been an object of considerable importance, will appear from *magna charta*, which has made a special provision in the 23d chapter, for the putting down of weirs and other obstructions in the rivers of England; and from stat. 25 Edw. III. c. 4. which sets forth, that "whereas the com-

mon paffages of boats and fhips in the great rivers of England, be oftentimes annoyed by inhanfing gores, weres, ftakes, &c. in great damage of the people: it is eftablifhed, the fame fhall be cut and utterly pulled down, without being renewed, and that writs be fent to the fheriffs to do execution." After two other unfuccefsful attempts by ftatutes in the fucceeding reigns, to prevent the free navigation of the rivers from being obftructed by individuals, intent upon fifhing, embanking land, or building mills, bridges, or making fords, the ftatute of the 4th of Henry I. chap. 12, appointed fpecial commiffioners for carrying the above ftatutes into effect; whofe powers were continued and enforced by two other acts, prior to the 23d of Henry VIII. chap. 5. which being entitled, "The Bill of Sewers with a provifo," appointed a general commiffion of fewers, with large powers that are ftill in force and acted upon, for making laws and ordinances, and compelling obedience thereto, for the "removing and preventing of impediments and annoyances on rivers, ftreams, and floods, whereby the paffage of fhips and boats might be letted or interrupted." And by the ftatute of Edward VI. chap. 8, the laft mentioned and former ftatutes were confirmed and made perpetual. During the above period, feveral other ftatutes were alfo made, for removing obftructions in particular rivers, of fome of which we fhall have occafion to fpeak when we come to mention thofe rivers.

The general laws of the land proving fo very ineffectual for protecting internal navigation from the encroachments of individuals and the effects of neglect, this probably fuggefted the propriety of thofe particular grants or ftatutes which we find enabling corporations, and in fome inftances individuals, to take particular rivers under their charge, and to receive tolls or dues from the veffels navigating within their particular diftrict. In procefs of time, as population increafed, and the advantages of water carriage became more apparent, further grants and acts of parliament were made, authorifing companies or individuals to extend the navigation on certain rivers further into the country, generally to reach fome city or great town; thefe acts, fome of which we fhall particularize hereafter, generally enabled the parties to deepen, and in fome inftances to ftraiten the courfe of their rivers, to embank them where too wide, to erect jetties and fluices, to make flafhes for furmounting the fhallows or rapids, and in later times to erect pound-locks for gaining the afcent to the different mill-dams upon the river. But the conftant tendency of rivers, efpecially rapid ones, to caft up banks of fand or gravel in particular places, their deficiency of water in times of drought, and fuperabundance in times of flood, the ravaging effects of thefe laft in deftroying the works erected for the ufe of the navigation; as happened on the river *Avon* between Chriftchurch and Salifbury; on the river *Stour*, between the Severn and Stourbridge; on the river *Calder*, between Wakefield and Efland, and on feveral others which might be mentioned; the great labour and difficulty of towing or dragging veffels againft the ftream, efpecially where there was not a towing-path for horfes, near to the channel of the river, and yet not fubject to be overflowed and rendered ufelefs in time of floods; the very lengthened courfe of moft rivers, arifing from their ferpentine, and, in fome inftances, varying channel, was not alfo among the fmalleft of the difficulties attending them: thefe, at length, fuggefted the propriety of leaving the bed of the rivers in fome inftances for a new cut for the navigation acrofs a neck of land, with a pound-lock at its lower extremity. As thefe fide cuts and pound-locks were increafed in number, to fhorten the courfe of the rivers, their fuperior advantages became fo apparent, that a company of gentlemen and merchants, who had in 1755 obtained an act of parliament authorifing them to make *Sankey Brook* navigable from the Merfey river to near St. Hellins, in Lancafhire, with the powers at that time ufual in navigation acts, for the purchafing of land and other things neceffary for the intended navigation, at a fair eftimate to be made by commiffioners named in the acts they determined, after mature deliberation, to avoid the bed or channel of the brook altogether, and to make one entire new cut or canal, as near as convenient to the bed of the river, with locks thereon, in fuch places as the falls of the ground fhould render neceffary; and this canal they accordingly effected about the year 1760, fupplying its higheft pound or level with water, by a cut or fender from the Brook. Thus navigable canals had their rife in England; but, a lefs fortunate fet of gentlemen, who under the power of an act obtained in the year 1730, for making the river *Stroudwater* navigable, from the river Severn to near the town of Stroud, although the act empowered them "to make as many new cuts as they may judge proper, and of what length and breadth they fhall think convenient;" yet when they had, about the year 1774, determined upon following the example of the *Sankey* proprietors, and in imitation of the duke of *Bridgewater's*, and feveral other canals, which had then been executed or were begun; by cutting a canal on the fide of the Stroudwater river, they were ftopped by an expenfive law-fuit, carried on by certain mill and land-owners in the neighbourhood: whereby the diftinction between the river navigation acts, and canal acts was eftablifhed by the Court of Exchequer, before which the cafe came to be argued.

About the year 1757, the *Duke of Bridgewater*, acquainted fully, no doubt, with what had been near 80 years before effected, on the canal of Languedoc, in the South of France, and fince in different parts of the Continent, conceived the idea of a canal for the purpofe of conveying coals from his eftate at Worfley in Lancafhire, to Salford near Manchefter. His grace, profiting as no doubt he did, by the works of that great French engineer, *Francis Riquet*, and by the advice of that great natural and felf-taught genius *James Brindley*, whom his grace called off, about the year 1758, from his employment as a mill-wright and engine-maker in this country, to perfect, and carry into execution, the great and important fchemes which he had projected, and for which he propofed and brought into parliament the firft act, with powers adequate to the great and extraordinary undertaking, of cutting a canal of feveral miles in length, not in the direction of any river or ftream of water, but croffing the courfe of feveral brooks, roads, &c. and through the lands of a vaft number of different perfons, all of whom were to be fully compenfated, though deprived of the power of withholding their lands or waters, or in any way obftructing the defign. In thefe refpects, the *Duke of Bridgewater* has not improperly been called the father of canals in England, while his engineer, the late *Mr. Brindley*, by his mafterly performances on the Duke of *Bridgewater's* canal, altered and extended as the fcheme thereof was, by three fubfequent acts of parliament, has fecured to himfelf, and well it fhould feem, from a comparifon of the great features, and minutiæ of execution in this the firft canal, with moft others in this country, even of the lateft conftruction, long continue to hold, that rank among the Englifh engineers, to which *M. Riquet* feems entitled among foreigners.

The courfe, thus happily opened by the Duke of Bridgewater, was quickly followed by new fets of adventurers, who were feen applying to parliament in almoft every feffion, for powers to raife a joint ftock on transferrable fhares, and

to make and maintain canals in moſt parts of the kingdom, many of which have been long completed, as our ſubſequent account of them will ſhew, and have contributed in a moſt eminent degree to the improvement of the country, as well as to the enriching of the individuals concerned in a great number of inſtances; in the laudable zeal of adventurers to extend, and of the people of great towns and proprietors of mines and great manufactories to receive, the benefits of inland navigation; numerous ſchemes have been adopted, where from the actual ſcarcity of water, or its previous appropriation to mills, a canal with locks was impracticable. One of the firſt of theſe ſchemes for diſpenſing with locks, was that of *Mr. Bridge*, about the year 1759, upon the *Stroud-water* river before mentioned, where the cargoes of the boats were diſpoſed in a number of boxes or frames, juſt adapted to the ſize of the boats; which boxes of goods were drawn up by cranes to be lodged in other boats on the higher level, and the reverſe in deſcending; which method was afterwards ſucceſsfully practiſed on *Bridgewater's* canal at Worſley, at Brieley Hill on the *Shropſhire* canal, and other places. The next mode ſeems to have been adopted by *Mr. Davis Drekart*, near the Tyrone collieries on the intended connection with *Blackwater* navigation in Ireland, about the year 1776; and afterwards by *Mr. William Reynolds* on the *Ketley* canal, where the boats were dragged up or let down inclined planes, not very different from the rolling bridges, long before in uſe in Holland and Flanders.

The neceſſity of an expeditious and cheap mode of conveying coals from the pits to the keels or ſhips, had, as early as the year 1680, introduced the uſe of wooden railways, for the waggons to move upon, between the *Tyne* river and ſome of the principal pits, and theſe by degrees became extended to a great number of other coal-works. Since the more general introduction of caſt iron, and its cheaper conveyance by means of canals, iron rails have been ſubſtituted in the place of the wooden ones before mentioned; and the uſe of inclined planes, or parts of the rail-way having a much greater declivity or ſlope than it is practicable to drag carriages up by means of horſes, has become very frequent in parts where the riſe of the ground required it, machinery being on theſe inclined planes adopted to ſupply the place of horſes.

Several years ago, an act of parliament was obtained by *Homfray, Hill, and Co.* for an iron rail-way, or tram-road from *Cardiff* to *Merthyr*, by the ſide of, and as a rival ſcheme of the *Glamorganſhire* canal, for 9 miles or more in length; ſince which, ſeveral other acts have been paſſed for rail-ways, and ſeveral of them executed, to the great benefit of the country, and the companies who conſtructed them; it has alſo become common within the ſame period, to authoriſe canal companies to conſtruct rail-ways, as collateral branches from their canal, to mines or other great works or to large towns within certain diſtances of ſuch canals; by which their benefits have been amazingly extended: moſt of the latter acts have alſo authoriſed the adoption of rail-ways, of inclined planes, or of any of the expedients above-mentioned, or others as ſubſtitutes for locks, in ſuch parts thereof, as are not readily to be ſupplied with water, adequate to the waſte which locks occaſion. So many of theſe compound ſchemes for leſſening the expence of carriage have been already executed, or are in hand, that we have found ourſelves compelled, in order to preſent our readers with a connected and uſeful view of the ſubject, to include what we have to ſay on the ſubject of *rail-ways*, in the preſent article, as well as treat therein of *navigable rivers*, for the reaſons before ſtated.

Great Britain as well as every other iſland, and even a continent taken as a whole, has a range of high land paſſing nearly its whole length, which divides the ſprings and rain waters that fall to the oppoſite coaſts: we ſhall call this range dividing the eaſtern and weſtern rivers of Britain the *grand ridge*, and ſhall in our accounts diſtinguiſh on which ſide, or how each canal is ſituate, in reſpect thereof: and here it will be proper to remark, that no leſs than 22 of our canals now do or are intended to paſs this grand ridge, forming as many navigable connections between the rivers of the eaſt and weſt ſeas! theſe are the *Inverneſs and Fort-William*, *Forth and Clyde*, in Scotland; the *Leeds and Liverpool*, *Rochdale*, *Huddersfield*, *Trent and Merſey*, *Staffordſhire and Worceſterſhire*, *Wyrley and Eſſington*, *Birmingham*, *Dudley*, *Worceſter and Birmingham*, *Stratford*, *Warwick and Birmingham*, *Coventry*, *Grand Junction*, *Oxford*, *Thames and Severn*, *Wilts and Berks*, *Kennet and Avon*, *Dorſet and Somerſet*, *Grand Weſtern*, and *Bude and Launceſton*, in England: and what is not a little remarkable is, that the *Dudley* canal croſſes this grand ridge *twice*, the two ends being on the eaſtern ſide, and the middle part on the weſtern ſide thereof; the Kennet and Avon croſſes the eaſtern and weſtern branches, into which it divides on the Chalk Hills, weſt of Marlborough, by which parts of this canal are in the drainage of the weſt, the ſouth, and the eaſt ſeas! the *Coventry* canal alſo, by means of its Bedworth branch, croſſes the grand ridge twice. The populous and remarkable town of *Birmingham* is ſituate on high ground, near to the grand ridge, and has ſix canals branching off in different directions, either immediately therefrom or at no great diſtance, and what is ſingular, owing to a loop, or ſudden bend of the ridge at this place, no leſs than five of them traverſe the grand ridge, either by means of tunnels or deep-cutting.

When we propoſe to lay before our readers a more full and methodical account than has been given of the Britiſh canals, on which large ſums of money have been expended by individuals, and from which important and laſting benefits have been derived by the inhabitants in their immediate vicinity and by the kingdom at large; it is needleſs to ſtate any formal arguments, in anſwer to the miſtaken objections, which were 40 years ago commonly circulated, whenever a new canal was in contemplation; ſuch as their waſting of land, producing noxious and humid vapours, deſtroying the breed of our draught horſes, leſſening the coaſting trade and the nurſery of ſeamen, injuring old mines and eſtabliſhed works by enabling new ones to be opened, introducing pilfering workmen and boatmen into the country, &c. &c. To the more ſerious objections, ariſing from the cutting of eſtates and fields in two; the taking of water from mills, &c.; interfering with former navigations by canals or rivers, and even with roads, on which, in ſome inſtances, large ſums have been expended, and remain not reimburſed; to theſe and many others, we ſhall have the beſt opportunity of replying, when we come to mention the equitable proviſions which individuals have propoſed, and the legiſlature have in ſo many inſtances enforced, for ſecuring to every one an adequate compenſation for what he is called upon to give up.

General arguments in favour of canals are ſuperſeded by the rapidly improving and thriving ſtate of the ſeveral cities, towns, and villages, and of the agriculture alſo near to moſt of the canals of the kingdom, the immenſe number of mines of coal, iron, limeſtone, &c. and great works of every kind to which they have been conducted, and to which a large portion of them owe their riſe, are their beſt recommendation.

Juſtice requires our acknowledging the aſſiſtance we have received in compiling this account, from the *General Hiſtory of Inland Navigation by John Phillips*, from the three

numbers which are published of *John Cary's Navigable Canals of Great Britain*, from *C. Smith's*, *George Allen's*, and *Laurie and Whittle's* maps of the canals, &c.; from *J. Cary's large map of England, Wales, and part of Scotland;* from *Robert Fulton's Treatise on Canal Navigation*, from *William Chapman's Observations on Canal Navigation*, from *Joseph Plymley's Agricultural Report of Shropshire*, from *Zach. Allnutt's Considerations on the Navigation of the Thames;* from *Thomas Badeslade's*, and from *Nathl. Kinderley's Accounts of the Navigation of Lynn and Wisbech*, &c. from the *Agricultural* and *Monthly Magazines*, from *Dr. Anderson's Recreations*, from the *Annual Register*, from *Thomas Telford's Reports on the Caledonian Canal, &c.;* and from the writings of others, to whom we particularly refer.

To *Mr. William Smith*, engineer, of Buckingham-street, London, we are indebted for many valuable hints and information given on many points, as we are also to *Mr. Benjamin Bevan*, engineer, of Leighton Buzard, Beds.

When it is proposed to form any canal, the choice of a skilful and experienced engineer is an object of primary consideration. Without due attention to this object, many impracticable projects may be adopted, and large sums of money may be expended without accomplishing any important and useful purpose. In suggesting the principal qualifications that are necessary for rendering persons competent to be consulted or employed in undertakings of this kind, we shall merely specify some of those that have in an eminent degree distinguished, or that still no less conspicuously distinguish several of our own countrymen. A skilful engineer should undoubtedly possess a considerable degree of mathematical knowledge. Calculations, of which some are of the most abstruse and laborious kind, will frequently occur; and he should, therefore, be well acquainted with the principles on which all calculations are founded, and by which they are to be rightly applied in practice. An engineer should also have studied the elements of most or all of the sciences, immediately connected with his profession; and he should particularly excel in an acquaintance with the various branches of mechanics, both theoretical and practical. His knowledge should comprehend whatever has been written or done by other engineers, and he should have information in every department of his office from an accurate examination of the most considerable works that have been executed in all the various circumstances that are likely to occur. It is necessary, that he should be a ready and correct, if not a finished, draughtsman. He should also be conversant with the general principles of trade and commerce; with the various operations and improvements in agriculture; with the interests and connection of the different owners and occupiers of land, houses, mills, &c.; and with all the general laws and decisions of courts, pertaining to the objects connected with his profession. By an extensive acquaintance with the disposition, inclination, and thickness of the various strata of matter, which compose the soil or land of the British islands, he will be able to avoid many errors incident to those who are destitute of this knowledge, and to have the course and causes of springs, to which it leads. As the last, though not the least, of these qualifications of an engineer, which we shall enumerate, we shall add, that he should be a man of strict integrity. If, at this day, the affairs of any canal company should be entrusted to persons deficient in all or the greater part of the qualifications above enumerated, the managers of such a company will thus incur a serious responsibility to the proprietors and to the public. In this connection we think it right to mention an institution that had its rise in the year 1771, viz. "the Society of Civil Engineers," as admirably calculated to extend the influence of our present and more experienced engineers, and to bring forward to public notice others, who, in the course of events, are destined to second them. For further particulars relating to this society, we refer to the preface of the first volume of Smeaton's Reports, Nicholson's Journal 4to. vol. ii. and the article SOCIETY of *Civil Engineers*.

A proper engineer being fixed upon, the adventurers should not tie him down too closely, by restrictions as to time, but allow him leisure to consider, digest, and revise again and again, the different projects and ways, which will naturally in most instances present themselves to him in an extensive and thorough investigation. The engineer should be allowed to chuse and employ the most competent assistants, and to call in and occasionally to consult the opinions of eminent or practical men, as land-surveyors, agents of the neighbouring landed property, the principal and most expert commercial men of the district, and who are best acquainted with its trade and wants, any eminent miners, &c. &c.; and such men the engineer should be authorized liberally, and at once to remunerate for their services and intelligence.

Previous to the beginning of any minute survey or system of levelling, the engineer ought to visit personally, and endeavour to make a just estimate, and preserve memorandums of all the objects within the district under consideration; as of the trade and importance of all the towns likely to be affected by the undertaking, of all mines of coal, iron, &c. quarries of lime-stone, free-stone, slate, &c. or the situation where such can be found, of all manufactories of heavy and cumbrous goods, and other extensive works; and generally of every thing likely to furnish tonnage for a canal. By this time, if the district under consideration be of very considerable length, more than one, and perhaps several, different routes for the proposed canal have presented themselves: and it will be proper, while the engineer's assistants are carrying levels (using good spirit levels with telescopic sights) along each, and making rough sections of the ground, or brook or river along each line, himself to visit and pass along each of these, noting and weighing more particularly the principal difficulties which present themselves in each route, as summits or hills to be passed, or tunnelled through, vallies to be embanked across, with aqueducts over rivers or brooks, the greater or less plentiful supply of water, particularly at the summit levels, and how far the springs and streams of water are at present appropriated or essential to mills or gentlemen's pleasurable purposes, or to irrigation, or the land occupied by parks, turnpike roads, &c. The advantages of each route should also be as carefully noted; as the shortness of distance, connection with great towns, mines and works either on the line or by short and practicable side cuts or branches, the smallest number of locks, bridges, culverts, &c. In weighing all these circumstances, in order to determine on the most advisable line, it should never be lost sight of, that a canal is altogether a mercantile speculation, and cheapness of conveyance is the grand desideratum thereof: where, therefore, but few, if any, great towns, works, or mines are found upon a proposed line, and the principal object is to form a connection between the canals of a district more fortunately circumstanced in these respects, and the metropolis, or a great town, as in the case of the *Grand-Junction* canal lately completed, it is evident, that much ought to be done to obtain the shortest route that is practicable: if, on the contrary, the district under consideration has great towns, mines of coal, or great works distributed about it, some miles in the total distance may be properly allowed, and a more circuitous route adopted, to

embrace as many as possible of these objects, particularly coal-works; for it has been remarked, that the carriage of coals gives rise to the principal revenues of most canals; and some have even contended, that no canal can answer to the proprietors unless the carriage of coals be its principal object: there are, doubtless, some exceptions to this rule. It may be concluded, upon the whole, that no canal can be completed and brought into use, but the inhabitants and the agriculture of the district will shortly feel great benefit from it, whatever may be the result to the proprietors; yet in the stage of the business of which we are treating, it is the peculiar duty of the engineer to study the interest, and bring forward the probable advantages of the proprietors, fairly and without exaggeration, in order that the subscription may fill, and the work be enabled to proceed. Before determining upon the route of a canal, its connection with the neighbouring canals or river-navigations should be well considered, and the engineer should inform himself accurately of the quantum of benefit or injury likely to result to each of such existing navigations by the effecting of the new one, or how far their rivalship, or that of any other scheme which may at the time be in agitation, is likely to effect the one he is employed upon; in all the practicable routes, which present themselves for the new canal.

The most eligible route for the canal being settled in the engineer's mind, he will then proceed to make a rough calculation of the quantity of goods of each different kind, which may be expected to pass upon the line in a given time; he will also examine all the canals and rivers which the proposed canal is to connect with, and ascertain the widths and depths thereof, the sizes of their locks, and of the vessels usually navigating them. The engineer will now be able, well considering the nature of the ground the canal is to pass over, to determine on the most proper dimensions for the intended canal, and whether the probable supply of water renders it practicable to effect the rises and falls by the ordinary mode of locks; or whether inclined planes, or any other of the expedients which we shall more particularly enumerate hereafter, should be adopted: or even, whether a rail-way, in whole or in part, may not be preferable to a canal. The mind of the engineer will properly be exercised upon these questions, before a more minute and expensive survey and planning of any particular line are entered upon; because, the line, though passing through the same tract of country, will generally require to be conducted in a very different place for great lengths together, according to the size of the proposed canal; and inclined planes, or a rail-way in whole or in part, will introduce a still greater diversity in the routes that ought, under the different circumstances, to be pursued.

Robert Fulton, in his 4to. Treatise on Canal Navigation, published at London in 1796; *William Chapman*, in his 4to. Observations on the various Systems of Canal Navigation, London, 1797; *Thomas Telford*, in J. Plymley's 8vo. General View of the Agriculture of Shropshire, London, 1803; *Edmund Leach*, *Dr. James Anderson*, and others in different works, have recommended and enforced, upon principles more or less general and true in their application, a variety of schemes and methods of conveyance, by small canals, inclined planes, rail-ways, &c. of which we shall take notice under their proper heads, and of which the engineer will of course avail himself, as far as they appear applicable; as well as of any other inventions, which his own ingenuity or that of others may supply. Long levels may, in some instances, be obtained, without inordinate expence; and will often prove of great utility, in the saving of the time and trouble of passing locks in the neighbourhood of great towns, as in the cases of Coventry, which has the benefit of more than 73 miles of level navigation on the *Coventry*, *Ashby de la Zouch*, and *Oxford* canals; and of Manchester, which has 70 miles of level water by *Bridgewater's*, and *Mersey and Trent* canals, including 12 miles in the tunnel to the *duke of Bridgewater's* coal-works in Worsley Hill: Birmingham has 43 miles of still water, by means of the old *Birmingham*, the *Worcester and Birmingham*, the *Dudley* and the *Stratford* canals; and this upon so high a level, that the three last canals cross the grand ridge in that space: Lancaster and Preston have 42½ miles of level on the *Lancaster* canal; Wolverhampton enjoys the benefit of a level 40 miles in length, on the old *Birmingham*, and *Wyrley and Essington* canals; Liverpool has 28 miles of level on the *Leeds and Liverpool*, and Blackburn, 24 miles upon the same canal; Basingstoke has 22 miles upon the *Basingstoke* canal; Whitchurch 21 miles on the *Ellesmere*; Devizes 20 miles upon the *Kennet and Avon*; Bottesford 20 miles upon the *Grantham*; London enjoys the benefit of about 19 miles of level to Paddington, upon the *Grand Junction* canal; Glasgow 18 miles on the *Forth and Clyde*; Gloucester is to have 18 miles upon the *Gloucester and Berkley*; Shrewsbury has 15 miles on the *Ellesmere*; Stainsforth 15 miles on the *Stainsforth and Keadby*; Abergavenny 14 miles on the *Brecknock and Abergavenny*; Market Harborough 13½ miles on the *Leicestershire and Northamptonshire Union*; Shrewsbury 11½ miles on the *Shrewsbury*; and Cromford 11 miles of level on the *Cromford* canal. Another benefit will sometimes occur from long levels, by the bringing of all, or of a considerable number of the locks near together, as at Runcorn on *Bridgewater's* canal, by which they are more effectually looked after and kept in repair. Should it be necessary to return the water let down by the lockage, again into the higher pound by the power of engines, as is done on the old *Birmingham*, the *Barnsley*, and many other canals, the having of considerable falls in one place will be of material consequence; but still more so if inclined planes are to be used instead of locks, as on the *Shropshire*, *Shrewsbury*, and *Ketley* canals. In conducting the line of a canal, it will always be advisable, if other circumstances will permit, to bring two or more locks near together, and to erect a lock-house for the residence of a careful and proper person upon the spot, to look after and assist the bargemen in working the locks; where this had not been attended to upon some canals, but single locks were placed at great distances from each other, the company have, from experience of the damage such locks sustain, found it necessary to employ great numbers of lock-keepers, and often to build houses for the superintendance of single locks. Mr. *Chapman*, who appears to have well weighed the question, whether large or small canals ought to be adopted under different circumstances, observes, "that the system of small canals is particularly eligible in all countries where lime-stone, coal, iron-ore, lead, and other ponderous articles, not liable to damage from being wet, or likely to be stolen, are the objects chiefly to be attended to; and where the declivity of the country runs transversely to the course of the canal, which will generally be the case along the sides of mountains, at an elevation above the irregular ground at their feet. In those situations, the great falls or inclined planes may be made at the forks of rivers, so that the upper levels may branch up both the vales, and thus give the most extended communication. A situation suited for those canals will often be found in countries that are not absolutely mountainous, but where the ground regularly declines towards the vales of large rivers." The principles for which Mr. *Leach* has so strenuously contended, of re-

verſing the uſual order of beginning navigations at the loweſt points or the ſea, and extending them up the vallies towards the ſummits, and, inſtead thereof, beginning near the ſummit or ſource of the water, and continuing the level till the greateſt practicable falls are obtained for inclined planes, would, unleſs the moſt enormous expences were incurred for tunnels, deep-cutting, and embankments, prove too crooked and circuitous for a ready conveyance, as happened on the *Bude and Launceſton* canal, which was propoſed to purſue a ſerpentine courſe of 81 miles, between two places whoſe direct diſtance is no more than 28 miles! The long level of the *Oxford* canal, at its northern end, of which we have ſpoken above, appears among the moſt crooked of thoſe canals which have been executed, and is particularly ill adapted, to the great throroughfare or communication which it forms with other canals. Canals which are to form an immediate connection between the ſea or tide-way at different places, as the *Inverneſs and Fort William, Crinan, Forth and Clyde*, the *Iſle of Dogs*, and the *Glouceſter and Berkley*, muſt be of large dimenſions, or the principal advantages of ſuch a communication would be unattainable; in like manner, the communications between the ſea, and docks or harbours, will ſome of them require to be of ſtill larger dimenſions, as the *Grimſby, Ulverſtone, Dee* new channel, &c. A ſyſtem compounded of *water-levels*, or lengths of canal on different levels without communication by locks, may ſometimes be found adviſable, as on the *Shropſhire, Shrewſbury, Ketley, Leiceſter*, &c. The advantages of being able to conduct a canal, in many inſtances, upon water-tight ſtrata, inſtead of rocky or porous ſoils, and perhaps without loſing ſight of any of the other important conſiderations mentioned, are ſufficiently great to induce engineers to become acquainted with the arrangement and particulars of the *ſtrata* within their diſtrict, by a minute and careful examination, or to call in the aſſiſtance of thoſe beſt informed on ſuch points. We have purpoſely omitted, till now, to mention the conſideration of the value or quality of land to be purchaſed for the uſe of the propoſed canal by different routes; convinced that ſome late canals have been materially injured by the narrowmindedneſs of thoſe who would avail themſelves of cutting through common or low-prized land: even the general conſideration of expence, in the works of a propoſed canal, ſhould hold but a ſubordinate place in the mind of an engineer in the preſent ſtage of the buſineſs, becauſe contracted views in this reſpect may fruſtrate the attainment of a great portion of the benefits to be expected; and it cannot be doubted that any ſcheme of conveyance will beſt anſwer to the adventurers and the public, when conducted upon the principles moſt adapted to the caſe, let the expence be what it may; and fortunately, the commercial and public ſpirit, aided by the means of individuals collectively in this country, has long ſhewn itſelf equal to any enterprize however bold, where advantages can be ſhewn materially to preponderate.

In the particular ſurvey of the line propoſed, all the knowledge of the moſt expert and competent engineers, with the moſt able aſſiſtants, will be requiſite. The rough ſection of the propoſed line, before taken, will enable the engineer to ſee the places of the heights and breadths of the various ſummits, or ranges of high land that are to be paſſed, and whether any two or more adjacent ones can be connected by a long ſummit level, without deſerting any conſiderable town or point of trade, which will diminiſh the difficulties of ſupplying the canal with water, as every ſuch junction of ſummits preſerves the water of two lockages, beſides preſenting ſo many more points at which the canal can be ſupplied with water, from ſprings and rivulets above its level, or where, in leſs favourable ſituations, the ſame can be collected in a lower level to be pumped up. The extremities of the principal ſummit or ſummits being thus nearly ſettled, it will next be inquired, how far it is practicable and adviſable to reduce the height of the ſame by deep-cutting or by tunnelling, or both of them. The adviſable height of the ſummit-level of the canal being ſettled, if water is not in ſufficient plenty, a minute ſurvey of both ſides of the range, or ridge which is to be paſſed, and of all its connecting heights, for a conſiderable diſtance on each ſide of the line, ſhould be made by tracing the propoſed ſummit-level along all the ſides of the hills, particularly noting all the ſprings or rivulets which riſe above and croſs this line; and all ſuch ſtreams of water ſhould be accurately gauged, and the quantity of water which they diſcharge per day determined; the ſame ſhould alſo be done for all the rivulets or ſmall ſtreams that croſs the line of the canal throughout its courſe; and theſe experiments ſhould be made not only where the ſtreams croſs the line, or levels, but at a conſiderable diſtance above and alſo below thoſe points, the particulars of which experiments ſhould be regularly and formally entered in a book, with all the attendant circumſtances, and ſigned by the parties preſent at the making of them; as the ſame may prove of the moſt important uſe in future, either for detecting any ſecret leaks in the canal, or feeders by which any of theſe ſtreams may be increaſed; or, in caſe of future claims being made for the water, or the diminution thereof by mill-owners or others, the company may be prepared, either to make a juſt retribution, or to reſiſt ill-founded or ignorant claims with effect. For calculating the quantity of water diſcharged through gauges or apertures of different kinds and dimenſions, theorems ſhould be uſed which make the neceſſary allowance (deduced from experiment) for the form of the channels or apertures; ſuch will be found in Dr. *Young*'s abſtract of M. *Eytelwein*'s learned German work on Hydraulics, printed in the Journals of the Royal Inſtitution, as alſo in *Nicholſon*'s *Journal*, 8vo. iii. 25. The ſurvey of the ſummit of which we were ſpeaking, ought to be accompanied by a plan, on which ſhould be laid down the exact courſe of every valley and range of hill above the level of the propoſed ſummit, with every particular of the nature of the ſoil in each; that in caſe reſervoirs therein ſhould be found neceſſary to collect rain or ſpring water, the neceſſary extent and probable ſupply of ſuch can readily be determined at a ſubſequent period. From one end of the propoſed ſummit-level it will be right now to proceed with the ſurvey, tracing the level accurately and marking the ſame by pegs or ſtakes, that will laſt for ſome time, and be known by the ſurveyor, who is to follow and make a plan of the line; the levels being frequently transferred to what are called bench-marks, upon the trunk of a tree, a large poſt, or a building, the ſame being noted ſo particularly in the field or ſurvey-book, that they may be readily found for years afterwards. We ſuppoſe the engineers, by this time, to have ſettled the riſe that each lock ſhould have, according to the dimenſions adopted for the canal, the probable ſupply of water on the ſummit, and other circumſtances; the ſummit-level will be traced as above, till the proper place occurs for making a fall of two or more locks, at about 100 yards or a little more from each other; and the places of theſe falls being marked, the level is again to be purſued and traced from the bottom of them, and marked out as before, till the opportunity occurs for another pair or more of locks, or till ſome obſtacle, as a gentleman's park, houſes, gardens, orchards, mills, roads, &c. preſent themſelves at a diſtance; when it will be proper, after referring the level arrived at, to a proper and permanent mark, to proceed

forwards, and to examine and well confider the different ways and levels, if more than one of fuch prefent themfelves, by which the obftacle can be paffed. From the moft confined part of the courfe for the canal, owing to the obftacle, it will be right to level back, till the former work is met, and, in many inftances, confiderably overlapped, in order to determine the moft eligible mode of bringing the two levels together, upon the principles before ftated, if they can be applied, either by adding another lock, or taking one from any of the fets of them which had been before marked out, as occafion may require, and marking out the new levels thereby occafioned: the line between the fummit and the firft obftacle, or confined part of the courfe, being thus adjufted, a new point of departure is to be taken from fuch obftacle, and the level purfued as before, till the fall for a pair or more of locks can be gained, at the proper diftance from each other. It is probable, that but few fets of locks can thus be determined upon before fome new, and perhaps more formidable obftacle will prefent itfelf, which it will be neceffary to break off for, and proceed forwards to confider, and to obviate as before; or the new difficulty may confift of fome confiderable lateral valley coming into the one which we are fuppofed to be purfuing, which may occafion an infurmountable or unadvifable length of embankment and aqueducts neceffary, in order to pafs it; or fome gentleman's feat, mill, or town, may be found fo completely occupying that fide of the valley down which the line was proceeding; that the engineer may find it neceffary to go back and revife a great deal of what he had done, perhaps quite up to the fummit, and perhaps to take a new courfe down the other, or oppofite fide of the valley, or at leaft to determine where, with the leaft expence of embankment and aqueducts, the valley can be croffed to gain the oppofite fide. The places of the different fets of locks, or of fingle ones, if they cannot be avoided, and the line between each being adjufted anew, we will fuppofe the work again to proceed, till fome new obftacle prefents itfelf; this may be either a total change in the courfe of the valley that the line was purfuing, fo as to render it neceffary to begin to mount fome other valley towards a new fummit; or fome gentleman's park, who is adverfe to the meafure, may fo completely occupy the valley, down which the engineer is intent ftill upon purfuing his courfe, that it may be neceffary to fearch out for the moft eligible place for tunnelling through the hill into fome adjacent valley, which is about to fall into the main valley. An inftance of this latter kind occurred at King's Langley upon the *Grand Junction* canal, where the firft Act provided for a tunnel of near half a mile in length, in order to avoid Cafhiobury park: but the fame has fince been altered, and the courfe of the canal continued through this and fome other parks, contributing not lefs to them in point of ornament than to the public in utility. It may happen, in cafe of a change of the direction of the valley, rendering it neceffary to leave it, that fome other valley may be at no great diftance, into which the canal muft be conveyed by a tunnel; and in order to render this practicable, it may be neceffary to go back, and conduct a good deal of the line that had been done upon a new and much higher level, by omitting fome of the locks, in order that the level may be conducted through, and fupply the propofed tunnel: in accomplifhing this, the former obftacles may recur again, or new and more formidable ones may be prefented. In this way, the patience, perfeverance, and abilities of the engineer muft be exercifed, until a practicable line of fome length is obtained, and ftaked out; when the affiftant land furveyor muft follow, and make a correct and particular plan of the line of the feveral propofed locks, embankments, tunnels, &c. upon the fame, and of the feveral fields or pieces of land through which it paffes, or that come within 100 or 150 yards of it in any part: it will likewife be the bufinefs of the furveyor to afcertain, with the utmoft care, the boundary of every parifh and townfhip, what county each is in, the proper names of the owners and occupiers of every piece of land in each, however fmall, upon or within that diftance of the line, with reference to the fame upon his plan; and to defcribe correctly all public and private roads and paths that crofs or interfect the line, and to and from what places they lead; the courfe of all brooks or ftreams of water, and particularly fuch as lead to, and contribute to the fupply of any mill: the fituation of the houfes and towns upon the line, or within fome miles of it, fhould alfo be determined; the nearer they are the greater accuracy will be neceffary. We will now fuppofe the engineer proceeding with the line, from the end of a tunnel into a new valley, the courfe of which downwards is in the proper direction; the fame procefs is to be repeated as was purfued in defcending from the firft fummit, until this new valley changes its direction, or until fome great town or work has been reached, and it becomes neceffary to change the courfe of the canal, and begin to afcend fome new valley or plain towards a new fummit, or towards fome mine or work, at which the canal is to terminate: to the new fummit it will be neceffary to proceed, and after fettling the height of the fummit level, and taking all the preparatory fteps for afcertaining the fupply of water, and other circumftances of this fummit, as defcribed refpecting the firft, the levels will be traced from this fummit downwards, working backwards or up again, as often as obftacles may render it neceffary, until the former work in the valley is met, and a proper junction of them contrived: the whole of this part being adjufted, the furveyor may proceed as before, with his plan and particulars: while we fuppofe the engineer returned to the firft fummit, and from which he will conduct his line, and avoid the obftacles thereon, in the beft way that his ingenuity can fuggeft, until he arrives at the navigation or fea-port, at which his canal is to terminate, and where bafons or docks, more or lefs capacious, according to the expected trade, and wharfs, cranes, and other conveniences, may want planning, for the accommodation of the traders and the public: all which the furveyor will proceed to furvey and plan, as before mentioned. It may be neceffary to remark, that every town, mine, or work, which happens to lie higher than the line, and to which a collateral cut is to be carried, muft be confidered as a feparate fummit, and provifion for fupplying the lockage thereof muft be made, and fuch of the examination before defcribed gone into, as may appear neceffary; fuch towns, &c. as lie below the line, and are to have cuts or branches to them, will require water to be let down out of the line to fupply their lockage; on which accounts, it is highly defirable, whenever the fame is practicable, to conduct the line upon fuch a level, that the collateral cuts may be upon the fame level, by which the trade thereon is much facilitated, and lefs water required.

A complete plan of the line, and all the projected collateral cuts, feeders, refervoirs, &c. being finifhed, the engineer will enter on a moft careful revifal of the whole fcheme, with this plan in his hand; on which all the places where culverts or drains will be required, are to be marked, as alfo the proper places for the bridges, and the neceffary alterations of the roads and paths, which will be cut off by the canal, fo that the public may not be inconvenienced and turned long diftances round about, and ftill, that as few

bridges as poſſible, and thoſe in the leaſt expenſive places, may be erected. In ſome inſtances new channels will require to be cut for brooks and water-courſes, to a conſiderable extent, in order to ſave culverts, or bring them to the moſt deſirable ſpots. For proper ſecurity againſt accidental errors, the whole of the levelling ſhould now be gone over again, and the ſeveral bench-marks compared, and renewed with the utmoſt care by the engineer's aſſiſtants, while he is proceeding with the neceſſary inquiries and calculations, for an eſtimate of the whole expence of the undertaking.

In a great number of inſtances it will be found, that the ſupplying of a canal with water, occaſions no inconſiderable ſhare of the whole expence, either in the firſt coſt of mills or ſtreams of water, in land for, and labour in, conſtructing reſervoirs, engines to pump up water, &c.; or annually ever afterwards, in the fuel for, and repairing of, engines, hire of water from mills in dry ſeaſons, &c.; this ſubject ſhould, therefore, employ the moſt ſedulous attention of the engineer, both to make the moſt economical uſe of what ſtreams he finds, to procure other ſupplies of water at the leaſt expence, but above all, to ſecure an abundant ſufficiency. The dimenſions and height of the locks, and breadth of the canal being ſettled, an accurate calculation made of the quantity of water required to fill a lock; and, with the largeſt probable number of boats that will paſs in a day, the quantity required daily in every part of the canal; this, with a due allowance for the evaporation, from the ſurface of the whole canal and its reſervoirs, and for the ſoakage that will take place into the banks, however well they are conſtructed; will ſhow the number of locks full of water that will be required, from all the different ſources. We have ſpoken of the ſteps proper to be taken for aſcertaining the whole ſupply that can be had above the ſummit's level; and it will often be neceſſary to make a ſimilar inveſtigation, on points below that level, and to conſtruct reſervoirs in ſuch ſituations, to ſupply the neceſſary lockage, for local trade upon the line, near any great town or works, which does not extend to the ſummit, as alſo to ſupply the evaporation and ſoakage of long lengths, in ſituations where feeders or ſprings cannot be taken in by the way; another uſe of reſervoirs in leſs elevated ſituations may be, to compenſate mills that are lower down the ſtreams for the water that is taken for the uſe of the canal from the higher branches, or near the ſources of ſuch ſtreams. For Mr. *William Jeſſop's* obſervations on this ſubject we refer to William Pitt's General View of the Agriculture of Staffordſhire, and to the *Repertory*, vol. iii. p. 243.

There appears no reaſon, under the preſent ſtate of things, why the owner of a mill or ſtream of water ſhould not be compellable to part with the ſame, for the purpoſes of a public canal, any more than another man to part with his field, except the accommodation which the public receive from ſuch mill; and where the ſame, or a ſuperior accommodation, can be enſured to the public, ſurely this ſpecies of property ought to be put upon the ſame footing with land in general. See Dr. *James Anderſon*'s Eſſays, vol. iii. p. 68 to 76.

It ought to be conſidered, that the preſent ſtate of our canals and inland navigations, and eſpecially the extenſion of them, which we are now ſuppoſing, remove one of the principal objections to ſteam engines, by enabling new mines of coals to be daily opened, and the products thereof, as well as of the old mines, to be regularly and cheaply conveyed to every ſituation where engines can be wanted. We would not, however, be ſuppoſed to recommend the annihilation of water-mills; on the contrary, it hath long appeared to us, that their number and their power might, in ſome, and perhaps in moſt inſtances, be greatly increaſed, and yet all the purpoſes of canals be fully anſwered, and thoſe moſt capital improvements of irrigation and drainage at the ſame time extended, to very large tracts of land; for this purpoſe it would be neceſſary, that an entire valley of conſiderable extent, that has a good ſtream of water through it, as the *Colne*, or the *Lea* near London, for inſtance, ſhould be put under a ſyſtem of improvement. A thoroughly competent engineer being employed upon ſuch a work, would be able to conduct a canal rather of large dimenſions perhaps, along one ſide of the valley downwards, until three or four locks, or a fall of 20 to 30 feet was obtained; and, the water in the pound below ſuch ſet of locks to be a ſmall diſtance below the level of the ſurface of the ground, in the loweſt part of the valley at that place, as this would enable the whole ſtream of the river to be taken into the next length of level, as often as occaſion ſhould require it: this new level would be traced, until, by the fall of the valley, it has reached the ſides of the hills, and proceeded with until another ſet of locks, three or four in number, can be obtained, and a deſcent made again to the level of the loweſt point of the valley: this proceſs to be continued through the whole length of the valley, under improvement. The next conſideration would be, a deep and effectual drain, to be carried up through the whole length of the valley, purſuing the loweſt ground, and the middle of the valley nearly, in ſuch parts where the hills on each ſide riſe equally abrupt; but where, as often happens, the deſcent to the valley on one ſide is very ſudden and ſteep, and on the other ſide long and gradual; in all ſuch caſes the drain ſhould be conducted nearer to the abrupt than to the eaſy ſide of the vale, becauſe here the peat or alluvial matters, with which ſuch valleys are choaked up, will be found the deepeſt, and the ſprings in the gravel underneath ſuch peat, the moſt copious and the moſt confined; the new drain ought, in general, to reach the gravel under the peat or filth; and where this ſhall be found impracticable, large auger holes ought to be bored at ſhort diſtances from each other, quite through the conſolidated peat and filth, to the gravel, to ſet the confined ſprings therein at liberty. Theſe principles of draining a boggy valley we have ſeen ſucceſsfully practiſed in the village of Crawley, below Wooburn in Bedfordſhire, by an agent of the late worthy *duke of Bedford*.

If the fall in the new drain ſhould be found very conſiderable, the ſame muſt be reduced, by placing weirs or well-falls at proper places, to let the ſtream down in an harmleſs manner, which would otherwiſe diſplace the gravel and ſand under the peat, and the ſame would cave in, ſo as to fill up and deſtroy the drain: another excellent uſe of theſe well-falls or weirs will be, to furniſh ſo many points, where the whole ſtream, including the ſprings, can be taken out to ſupply the upper end of the levels of the canal before mentioned, or for the purpoſes of irrigation; as was intended and provided for, in the Crawley vale that we have been ſpeaking of. To all the exiſting mills, which are not too ruinous or badly conſtructed to be worth improving, the channels to the water-wheels ſhould be deepened up from the main drain, or, perhaps, in moſt inſtances, new and more direct ones cut. It will now be practicable for the engineer, in moſt if not in all caſes, to conſtruct an *over-ſhot* water-wheel upon the ſame axis that before carried an *under-ſhot* one, turning the ſame way and with the ſame velocity as before, ſo that the internal machinery of the mill will need no alteration; and the requiſite quantity of water for working theſe new wheels, which in moſt caſes will be inconſiderable, may be conveyed from the canal on the ſide of the adjoining hill, in

aqueducts or elevated troughs of no very expenſive conſtruction, perhaps of caſt iron, or in pipes, which may be conducted under ground, and riſe up to ſmall reſervoirs or pentroughs above the wheels. As many of the mills will be found ſituated on the oppoſite ſide of the vale from the canal, it may be proper and adviſable in moſt caſes, to conſtruct a cut or water-carriage of ſufficient dimenſions, and with a very ſlight fall, along that other ſide of the vale, beginning frequently at the weirs or well falls in the main drain or new brook, and purſuing the level nearly, as far as is found requiſite; which cuts will much extend the benefits of irrigation, and give opportunities, perhaps, of conſtructing new mills, with over-ſhot wheels of large diameters and proportionate power, to be ſupplied therefrom. In like manner, ſeveral new and powerful over-ſhot mills may perhaps be conſtructed near to the ſeveral ſets of locks upon the canal, without endangering the ſufficiency of water for the lockage: this practice of uniting navigation and mill improvements at the ſame time, we were much pleaſed to ſee enforced by Mr. *Thomas Telford*, in his Report of 1801, printed by order of parliament, upon the intended *Inverneſs and Fort William* canal, p. 46: and the ſame has been ſuggeſted as an appendage to the Woolverton embankment on the *Grand Junction* canal; ſee the *Agricultural Magazine*, vol. viii. p. 24. New and improved mills may often be conſtructed where the point of a hill at a great and ſudden bend of the river can be tunnelled through, from the river on the upper ſide, as appears to have been done at Shrewſbury on the *Severn*, and at Stanley on the *Tay* rivers.

Where the new drain or brook courſe connects with the levels of the canal in the improvement of a valley, as above propoſed, if floods are to be apprehended, or the water is ever found very thick and muddy, weirs or over-falls ſufficiently large to let the flood eſcape down the drain muſt be conſtructed, and ſtop-planks provided to be put down acroſs the canal occaſionally, or a lock capable of a very ſmall fall conſtructed, to be occaſionally uſed, to prevent very muddy waters from entering the canal to ſilt it up. It will frequently happen, that brooks which are making their way laterally into a valley under improvement, may by an alteration of their channel for ſome diſtance up the collateral valley, be brought into the canal in places where a conſiderable elevation on the ſide of the hill has been attained, in ſuch caſes a circular weir or well-fall ſhould be conſtructed in the centre of an enlarged part of the brook, before it arrives at the canal, as has been done by Mr. *James Brindley*, at the mouth of Medlock brook at Mancheſter, on *Bridgewater's* canal; a proviſion for ſtop-planks, at the junction with the canal, will alſo be proper, to be enabled to turn occaſional muddy water down the well fall inſtead of into the canal. In order to preſerve a ſufficient elevation in the water-courſe, for ſupplying of mills, or for irrigation, after the canal has deſcended a ſet of locks, and is conſequently too low for this purpoſe, a cut or water-carriage may be taken out of the ſummit's level, and carried on along the ſide of the hill with a proper fall, as far as may be neceſſary. This ſyſtem of improvement in a valley, is capable of being combined with an extenſive application of reſervoirs, for equalizing the head and collateral ſtreams which ſupply ſuch valley, as recommended by Mr. *W. Jeſſop*.

In caſes where the land or park owners cannot be brought to concur in a general ſyſtem of improving a valley, it would often be worth while for a canal company to obtain power from the legiſlature to purchaſe all or moſt of the mills in a valley, through which their canal is to paſs, paying, in the firſt inſtance, the utmoſt value for them; and being alſo bound to erect the ſame number of mills, of equal or ſuperior power, and adapted to the ſame purpoſes, to be ſupplied from higher levels in the manner we have been deſcribing; ſuch new mills to be offered at a fair price, to be ſettled by indifferent perſons, to the owners of the adjoining old mills, before the ſame are diſturbed in the uſe of the old mills; and in caſe of their refuſal to purchaſe, the ſame to be next offered to the perſons who may be tenants to the old mills (in order that they may not be thrown out of employ); and then to any other perſons inclined to become purchaſers, on ſuch terms as they and the canal company could agree upon.

Sometimes it may be practicable to make a bargain for taking weekly into the canal, a ſtream of water which ſupplies a mill, only from Saturday night to Sunday night, paying a fixed rent for the ſame, to be ſecured by the act; an inſtance of which occurs upon the *Montgomery* canal.

The ſubject of ſupplying water for a canal having been amply illuſtrated, we ſhall now return to the reviſal of the ſurvey, and making an eſtimate of the expence of the undertaking, on which we ſuppoſed our engineer to be employed. In reviſing the ſurvey of the line, it may be proper for the engineer to cauſe holes to be dug at certain diſtances, as deep as the canal will require to be cut, or deeper, to inform himſelf more perfectly of the ſoil to be cut in, and the expence attending the ſame, noting particularly the height to which ſprings may riſe in the ſeveral holes. And here it may be proper to notice a very common error, into which the perſons entruſted to execute canals have fallen, in ſuch parts where ſprings appeared beneath the ſurface in the cutting, by concluding that the canal would make water, as they term it, in ſuch parts, and that puddling was unneceſſary; but where too often it has afterwards happened, that ſuch ſprings, from having a variety of other vents or outlets, at or very near to the ſame level, and were, therefore, incapable of being dammed or raiſed much higher than they then appeared; when the canal has come to be filled with water to a higher level, the courſe of ſuch ſprings has been reverſed, and the porous ſtrata through which they paſſed have ſerved to abſorb and diſcharge the water at other places, to a very fatal extent. Land-ſprings, or ſuch as run only in winter, have generally the ſame effect, and in ſummer as copiouſly take in water, when their own ſource fails, as they before diſcharged it. The difficulty of puddling or lining out ſprings, on account of the powerful effort they make to force their way through the lining, as long as the canal remains empty at firſt of water, will induce a careful engineer, to endeavour to avoid, if practicable, all ſprings that will not at all times riſe to a higher level than the water is to ſtand in his canal. It will be part of the buſineſs of this reviſal of the line, to examine what can be done to ſtraighten the canal, we mean as to ſudden bends, by ſmall lengths of deep-cutting, and others of embankment, to correct the plan accordingly, and to eſtimate the extra expence of all ſuch works. The lengths and ſolid contents of the ſeveral embankments, and the diſtance from which the ſtuff or ſoil muſt be fetched for the ſame; the lengths and dimenſions of all the deep-cuttings, and the diſtance to which the ſtuff muſt be removed; the lengths of the tunnels, and number and depths of the ſeveral ſhafts or tunnel-pits that will be neceſſary; the lengths of headings or ſoughs that will be wanted to drain the tunnelling works; theſe, and all the great variety of other works, ſome of which we have already mentioned, and others that we ſhall have occaſion to mention in the ſequel, being particularly ſtated, and prices fixed to each ſpecies of work and kind of material; and theſe prices ought by no means to be below the current prices of the beſt articles of the kind at the time, but due allowance

ſhould alſo be made for the advance of prices, which will take place during the execution of the work. The total probable expence, with a due allowance for contingencies, being thus obtained, the engineer will prepare his general report and eſtimate, to be laid, with the plan, before a meeting of the adventurers or propoſed proprietors.

The next ſtep in the progreſs of this buſineſs, after the appointment of a ſolicitor of competent legal knowledge, is an application to parliament for an act, empowering the parties concerned to complete their undertaking.

From the earlieſt times, the parliaments of this country have found it neceſſary to adopt certain ſtanding-orders, or general rules, to be obſerved by the parties who applied for any act of a local or private nature; and theſe ſeem to have guided the conduct of canal projectors, till the number and variety of ſuch applications ſhewed the neceſſity of adopting, on the 7th of May 1794, thirteen ſpecial reſolutions, as ſtanding orders, relating to the introduction and paſſing through the houſe of commons, of any acts for navigable canals, or aqueducts, or for the navigation of rivers; to theſe another was added on the 16th June 1795, reſpecting intended reſervoirs and feeders to a canal or navigation; and another on the 25th June 1799, applying the former orders to rail-ways or dram-roads, as far as the ſame are applicable. The houſe of lords have a nearly ſimilar ſet of ſtanding orders, and one requiring a ſufficient number of copies of an engraved map of the intended canal, &c. to be delivered for the uſe of each member of that houſe.

The number of clauſes, relating to the conſtruction and management of a canal, are neceſſarily very numerous, and it were much to be wiſhed, that the propoſition of Mr. *John Chanel*, in ſeveral periodical works, for a general canal act, to contain all their general clauſes and proviſions, in the ſame way as the general highway and turnpike acts, and the general incloſure act, could be accompliſhed; it would much ſhorten and ſimplify the buſineſs of canal acts and management. Another general meaſure, relating to canals, we beg here to mention, although the application to parliament in the ſeſſion juſt now paſſed (1805) did not prove ſucceſsful, we mean the propoſal for a *general canal company*, for raiſing a large fund, to be inveſted in ſhares of canals not yet finiſhed, and for lending money at intereſt, to ſuch canal companies as may require it, to enable them to complete and render their ſeveral concerns more generally beneficial.

Mr. *William Chapman*, when ſpeaking of the navigations of America, ſays, (Obſervations, p. 64.) "It will be adviſable in a riſing country, to lay out the lines of canals approximately on its firſt ſettlement; reſerving a proper width for them, in the original grant of the lands, with power to exchange the land of that line, for any other found more convenient, on a full inveſtigation; and thus avoid all the difficulties attendant on thoſe meaſures in England." Does not the period of the incloſure of a pariſh here furniſh the ſame opportunity of conſidering the eligible line for a canal; and of ſo contriving the allotments that very few, or perhaps only one perſon's land may require to be cut into, upon the adoption of ſuch meaſures, and that without cutting up or deranging the ſyſtem of his or their eſtate? We were happy to ſee this idea acted upon, as far as irrigation is concerned, in the pariſh of Maulden, in Houghton-Regis near Dunſtable, (into which a cut from the *Grand Junction* canal was propoſed to be brought,) and in ſome other pariſhes in Bedfordſhire, about the year 1797, by the late duke of Bedford's agent.

One of the firſt objects of a canal act is, to incorporate and make a body politic of the proprietors, by a certain *name* and ſtyle, by which they ſhall have perpetual ſucceſſion and a common ſeal, and by which they may ſue and be ſued, and have power to purchaſe lands, to them, their *ſucceſſors*, and aſſigns, for the uſe of the undertaking, without incurring the penalties and forfeitures of the ſtatutes of mortmain; and to enable the company to ſell any lands ſo purchaſed. The ſelection of the name for a canal, is of more conſequence than would at firſt ſight appear. Since canal and rail-way companies have multiplied ſo very much, it is neceſſary on all occaſions to adhere to and uſe their incorporate or *parliamentary names*, a circumſtance which has not been attended to ſufficiently, but ſuch a variety of names have been uſed, in the printed accounts of events upon or relating to our canals, that it is often impoſſible to avoid miſtakes.

It has been uſual to enable the company to raiſe a fixed ſum of money, equal to or exceeding the total eſtimate of expences, by ſubſcription or ſhares; and, in caſe of this proving inadequate, to borrow a further fixed ſum upon intereſt, or on mortgage of the tolls. The many and expenſive acts of parliament that canal companies have been obliged to obtain in the courſe of their work, for powers to raiſe further ſums, and even for regulating and enforcing the mode of raiſing the ſums firſt authoriſed, ſhew the neceſſity of the engineer and ſolicitor paying great attention to this point, and to be careful to apply for powers ſufficiently ample.

The uſual amount of ſhares in canal companies is 100l. but inſtances of 50l. ſhares, and others of leſs or greater value, occur in ſeveral of theſe eſtabliſhments. Theſe circumſtances ought always to be particularly attended to in comparing or quoting the prices of ſhares in different concerns; and we ſtrongly recommend all future ſhares to be 100l. ones, eſpecially as the legiſlature will permit of half ſhares, or even lower diviſions, down to the eighth of a ſhare, as appears in the *Grand Junction* act, 43 Geo. III.

To prevent the intereſt of any individuals from preponderating, and to increaſe the number of perſons having an intereſt in the ſucceſs of the undertaking, it has been uſual to limit the number of ſhares which any individual can hold, under forfeiture of all above that number, except they came to him or her by will, marriage, or other legal proceſs.

The election of a committee of management, and all queſtions agitated in the company are decided by votes, not perſonally, but according to the number of ſhares held by each perſon, to a limited extent, and uſually two half ſhares carry one vote. The uſual limitation to prevent any individuals from poſſeſſing too great power in the company is, that no more than 15, or ſometimes 20 votes ſhall be given by one perſon; while in the *Newcaſtle-under-Line* only 6 votes are allowed; and in the *Croydon*, *Peak foreſt*, and *Thames and Medway*, no more than 5 votes can be given by any one proprietor.

General meetings of all the proprietors are provided for, on any important occaſion, as well as annually to elect the committee and officers.

Proviſion ſhould be made for progreſſive calls on the proprietors, by the committee, for their ſeveral ſubſcriptions; theſe ſhould be on as long notice as is eligible; but they muſt be prompt and ſtrictly enforced, or the progreſs of the works will ſuffer.

The enactments relating to purchaſing of lands, and aſcertaining the value thereof, where the parties and the company's ſervants do not agree, by means of the commiſſioners, will be neceſſary, who generally conſiſt of all the conſiderable land-owners of the county, or of a jury to be impannelled for ſuch purpoſe, theſe ought to be very clear and explicit: ſo ſhould the regulations and forms for ſelling and transferring ſhares in the concern.

The moſt ample powers ſhould be given to enter upon,

and dig, and conftruct, both the permanent and all temporary works which may be neceffary; with provifions, in cafe of refufal, to accept the compenfation offered for damage; that the commiffioners or a jury fhall fettle the fame without delay or further appeal, except, in fome inftances, to the next quarter-feffion of the county.

A claufe is generally inferted, confining the company to the line that is laid down in the plans that have been depofited with the clerk of the peace and with the houfe of commons, or within certain limits on each fide thereof; the ufual deviation diftance allowed is 100 yards; however, many inftances have occurred, which fhew how very important it is to the proprietors, that the line of the canal, and every probable caufe for the neceffity of deviation, fhould have been thoroughly examined and weighed by the engineer, and the line ultimately adjufted, before the plans are completed and delivered.

The prudent precaution of the legiflature, has always limited the width of land which canal proprietors have been empowered to purchafe for their canal, in ordinary cafes, without the free confent of the owners; this has been 26 and 30 yards, in the greater number of inftances, but in others the fpace allowed for the canal towing-path and fences has been lefs or greater, according to circumftances.

Where wharfs, docks, or bafons, or places for barges to turn and pafs each other, or where deep-cutting or embankments are required, it has been ufual to allow 100 yards in width to be purchafed; but from this allowance there have been occafional deviations.

Except in fome rare and peculiar inftances, like the *London Docks* in Wapping, the parliament will not give to any company the power of purchafing houfes or other buildings, gardens, orchards, yards, parks, paddocks, or planted walks or avenues leading to any houfe, except the previous confent of the owners thereof be obtained; and where this has been got, it is the fafeft way to infert a lift of all fuch owners, with a defcription of the property they have agreed to give up, as a fchedule to the bill: and the fame of all material contracts for mills, ftreams of water, or fprings, which the company may have made. Houfes built, or orchards, &c. made as obftructions, fince the furvey was made, and notices given, will not meet with the fame protection; and a claufe ought to be inferted to put them upon the fame footing with lands in general.

Powers fhould be given for erecting public wharfs, and for demanding and enforcing certain equitable rates of wharfage for goods, according to the length of their continuance on the company's premifes.

The toll, or rates of tonnage, which the traders are to pay to the company per ton per mile for the liberty of navigating upon the canal, or its various branches, rail-ways, or inclined planes, require the moft deliberate confideration, that every fpecies of trade may pay its proportion, and none be difcouraged or leffened by the expences of conveyance.

In fome cafes provifion has been made, that when the net profits of the concern exceed a certain rate per cent. the tonnage or tolls fhould be reduced.

There have been exemptions from tolls, on feveral canals, in favour of officers and foldiers on their march, with their horfes, arms, and baggage. Timber for the ufe of his majefty's navy, and government ftores of all kinds fometimes pafs toll free; fo do gravel or other materials for the making or repair of roads in moft inftances. In fome cafes, canals have been projected principally with a view to tonnage on lime, and other manures and agricultural objects and produce; but with this exception, it has been ufual to allow lime and all manures to pafs, either on very low tonnage, or abfolutely toll free, on the levels, and through the locks alfo on fome, particularly when the water actually runs over, or is within a quarter or half an inch of the top of the lock-weirs; in fome inftances, feveral hours notice is required, of boats with manure or road-materials intending to pafs any locks toll-free. In fome inftances, where a canal is to run parallel to a turnpike road, and is expected to leffen the tolls thereof, by the diminution of heavy waggons and carts, it has been ufual to compenfate or indemnify the creditors on fuch roads; and it feems equally juft, where a turnpike road croffes a canal, and is likely to have its tolls both ways increafed, that they fhould not be entitled to receive materials by the canal tonnage free.

Mile-ftones are directed to be fixed on banks of moft canals, for regulating the diftances and tonnage; in feveral inftances, thefe are directed to be placed every half mile, and in others one is to be placed at the end of every quarter of a mile.

We fhould far exceed our due limits, if we were minutely to recount the various expedients that have been adopted for conciliating the owners of lands, parks, mills, &c. who may more or lefs be affected by different canals. Thefe muft depend on a variety of local and incidental circumftances, for the adjuftment of which no general rules can be prefcribed. But in all cafes of this kind the canal companies have ufually propofed, and the legiflature has fanctioned, an adequate compenfation. Proprietors of land and their tenants are fometimes allowed the ufe of the towing-path, as a drift and bridle-way between their different lands, or to fome public road; the owners of the adjoining lands are often allowed to make, not only docks and bafons communicating with the canal, but collateral cuts of confiderable extent, to their mines and other works; but previous notice of all fuch intentions ought to be given to the company, that their engineer may examine the ground, and direct the neceffary puddling and other precautions, to fecure the line of canal from lofing water to a prejudicial extent thereby.

The company are often empowered, and fometimes required, to make collateral cuts, or rail-way branches to particular towns, mines, or works; and a very proper precaution feems to have been adopted in the *Somerfet Coal* canal act, that the parties to be benefited by fuch branches fhould firft give the company fecurity to make up the tolls thereof, by an annual payment, in cafe of their falling fhort of a reafonable intereft on the money expended upon fuch branches.

In fome inftances it may be neceffary, particularly on railways, to permit individuals to conftruct and manage fuch part of the works as pafs through their own park or ground, but fubject to the general fyftem of management laid down in the act; as is done by the *duke of Beaufort* on the *Swanfea* canal, and by *fir Charles Morgan* on the *Sirhowy* tram-road; alfo to conftruct particular parts, on being paid for the fame, as was done by the *Dee* river company, at the croffing of the *Ellefmere* canal.

Claufes are generally inferted, requiring the canal company to remove and clamp the top foil, or vegetable mould, to the depth of nine inches, from the whole width of the intended works; which, after the fame has been completed, and all the banks and excavations properly floped down, is to be returned and fpread upon them, fo as to render all the land, not actually occupied by the canal and works, capable of cultivation; but a fmall part of this top foil is wanted in general upon the banks, and it might, more profitably for all parties, be filled by the company's men into the carts of the neighbouring farmers, to be fpread upon the poorer parts of their lands.

Watering places for cattle are generally directed to be made,

eſpecially where the fields may have been deprived of their old ones by the cutting of their canal. In counties where irrigation is much practiſed, as in Wiltſhire and ſome others, it has been common to appoint ſkilful and reputable perſons to guard the intereſts of the irrigators, on the cutting of canals.

On the duke of *Bridgewater*'s canal, irrigation trunks were laid below the bottom of the canal, ſo that, by means of a harrow, or rather a large hoe, drawn along, the mud of the canal was drawn to the valve or orifice of the trunk when open, and the mud was thus conveyed to the meadows be-below. A ſucceſsful experiment was here alſo made, of bringing up barges laden with ſea fluſh, or mud taken up at low water, in the Merſey, and this was gradually poured or thrown out into the canal, over the irrigation trunks while running, by which means this valuable manure was at once conveyed to and effectually ſpread on the meadows below. We have been greatly ſurpriſed to find irrigation ſo little practiſed upon the lands below canals, which ſo perfectly admit of that improvement; were this ſubject properly attended to, in ſituations where water is plenty, we doubt not but ſome proprietors or leſſees of land would be found, who would readily contract with the engineer, on the part of the company, before the canal is completed, to pay an annual rent for certain quantities of water, to be let out by the company's agents, at ſtated times, through a trunk, which might be laid beneath, or level with the bottom of the canal for ſuch purpoſe, at a very eaſy expence, before the water was let into the canal; and even after canals are completed, there are ſituations where the intereſt of all parties might be ſerved, by laying trunks for irrigation; and perhaps farmers ought not, except in ſome few inſtances, to be debarred from conſtructing or uſing proper weirs at the ſame immoveable height, or a little higher than thoſe at the lock-gates, to take off the ſurplus water for irrigating during the winter ſeaſon.

Sometimes it will happen that a canal can be conducted on a proper level to ſuit the adits to mines, as at Worſley on *Bridgewater*'s canal, and ſome others; or perhaps the tunnel through a hill may be applicable to mining purpoſes alſo, as at Morwelham down, on the *Taviſtock*, near Ripley on the *Cromford*, the Harcaſtle tunnel on the *Trent and Merſey*, and others.

Coal-mines may be allowed to have the neceſſary paſſages for their works under a canal, but ſhould be reſtricted in the number, width, and height of theſe, as on the old *Birmingham* canal; or if the veins are near the ſurface, the ground may be ſo entirely broke in, that the canal would be deſtroyed, as has actually happened on ſome of the branches of the above-mentioned canal, near to Wedneſbury.

Reſpecting mills, it may be neceſſary ſometimes, where the canal is to be conducted near to eſtabliſhed mills, that they ſhould be ſecured againſt other mills in the ſame line of buſineſs being erected on the canal at that place, as in the *Sankey* canal act. Sometimes gauge-weirs, or ſelf-regulating ſluices, may be neceſſary to be maintained, to ſupply mills or other canals with a regular and conſtant quantity of water; inſtances of which occur on the *Rochdale* canal, and at the Amſworth reſervoir, on the *Nottingham* canal; the theory of the regulating ſluice, in the latter place, will be found in the *Gentleman's Diary*, 1799, p. 43. by that eminent mathematician and coal-worker, Mr. *Thomas Walker*, of Bilborough; and if theorems for the widths and heights of ſluices to diſ- [illegible] with advantage. Thoſe who may wiſh to ſee how the ingenuity of mill-owners can be exerciſed to ſecure themſelves againſt poſſible injury, or even to thwart a canal ſcheme, may perhaps conſult the *Croydon* canal act, for the clauſes relating to the Wandle river.

Where a connection is to be made with any other canal lying upon a higher level, or even the ſame level, where leakage or waſte of water is to be apprehended, that would be prejudicial to either of the canals, it is uſual to provide, that a ſtop-gate ſhall be erected at or near the junction, which one or both of the canal companies are empowered to ſhut and lock up whenever there is ſuch a lowering or draught of water upon one of the canals, as would endanger the ſupply or lower the head of the other; clauſes for theſe purpoſes will be found in the *Dearne and Dove*, *Dudley*, *Stratford*, *Warwick and Birmingham*, *Wyrley and Eſſington*, and other acts. And when any canal joins another, coming down from a hilly country, it is uſual to require tail-gates to be erected, with capacious weirs for preventing of floods from the upper canals making their way into the lower one, as in the *Aberdeen* canal. It will very often happen, that tolls or dues will be to be paid by barges for entering any of the exiſting navigations from the new canal, or *vice verſa*. And where the new ſcheme can be ſuppoſed to interfere materially with the trade on any former one, it has not been unuſual to guarantee that their net profits or tonnage ſhall not be leſs, after the completion of the new canal, than before; or ſometimes annual payments are agreed to be made as compenſations for the expected loſſes to older navigations; and in ſome inſtances, where the rivalſhip is expected to be very formidable, as on the *Douglas River* by the *Leeds and Liverpool*, and the *Derwent River* by the *Derby* canal, proviſion has been made, that the old concern ſhall be purchaſed by the new proprietors at a fixed ſum; the ſettlement of the various compenſations that may be neceſſary on a canal are often ſuch as to require the exertion of the utmoſt abilities of the engineer, with the moſt able aſſiſtance, as the very long and complicated clauſes in many acts will ſhew.

On applying to parliament for any conſiderable extenſion of a canal, or to raiſe more money, there are inſtances, and perhaps very proper ones, of enacting that the ſhares of certain diſcontented proprietors ſhould be purchaſed out of the new funds, as on the *Dudley*, the *Kennet and Avon*, and others.

So attentive has the legiſlature been, even to the comfort of proprietors or inhabitants near intended canals, that it has been enacted, as on the *Barnſley* canal, that where ſteam engines were to be erected in certain places, for the uſe of the canal, their fire-places ſhould be ſo conſtructed as to conſume the ſmoke.

Ample proviſions ſhould be made, for powers to make bye laws for regulating the trade upon the canal, for the form and dimenſions of the barges or boats to be uſed thereon, and for paſſing the locks, inclined planes, &c. that may be thereon. It is neceſſary to declare, that the canal is not to be ſubject to the interference of the general commiſſion of ſewers; manorial rights, and fiſheries in old ſtreams, or waters ought to be reſerved; and it would be well for the encouragement of theſe great national improvements, if the legiſlature would permit a clauſe to ſtand, as in the older acts for *Bridgewater*'s and other canals, that the proceedings and writings of the company ſhould be valid without ſtamps.

It has been uſual to enact penalties for a variety of offences likely to be committed upon the canal; and for malicious damaging or deſtroying of the works to declare the offenders [illegible] into conſideration at the period of framing the act of parliament, ſome of which we ſhall avoid repetition by mentioning, when ſtating what occurs to us on the practice of executing

and managing canals, to which we are now anxious to proceed.

The act of parliament for a canal being paffed, and therein the time and place for the firft meeting of the fubfcribers or proprietors thereof being fixed; one of the firft bufineffes of fuch meeting will be the election of a *general committee of management*, confifting of the moft independent, refpectable, and generally informed perfons among the proprietors. The committee of management will then proceed to elect a chairman and fubordinate officers; to fix upon their place of meeting, and to arrange the order of their bufinefs.

It will not often happen that the engineer can be fpared from the projection and fuperintendance of other great concerns, to attend to the cutting of the canal and erection of the feveral works, without the affiftance of a *refident engineer*, or more than one, if the line be of confiderable length, and diftant parts of it are intended to be proceeded with at the fame time; and the committee will do well to leave it to their engineer to recommend all fuch affiftant or refident engineers from among thofe who have been brought up or employed under him, or are well known and approved by him, for their mathematical knowledge and practical fkill, experience and attention in the feveral kinds of works that are to be executed. The attention of the committee fhould be directed to fixing upon fome *land furveyor and valuer* of refpectability and great practical knowledge, who has been ufed to and acquired addrefs in the negociation and fettlement of purchafes and exchanges of property of different kinds; and if he has before been employed upon canals he will be fo much the more fit. In this ftage of the bufinefs it may be well alfo for the committee to confider whether any *local committees*, or a *felect committee*, may be neceffary, to pay the more minute attention to, and to bring before them, the concerns of particular diftricts of the canal, and to ferve other purpofes.

The body of the proprietors, affembled in a general meeting for the purpofe of completing the organization of the affairs of the company, will proceed to the choice of a certain number of auditors of their accounts, and to fettle the falaries of all the perfons that are employed.

Moft canal acts direct, that two copies of the plan of the canal and book of reference, with any amendments or alterations that may have been made in parliament, are to be certified by the fignature of the fpeaker of the houfe of commons; one of which is to be lodged with the clerk of the peace for the county, and the other with the clerk to the company, who are required to produce the fame, and fuffer copies or extracts therefrom to be at any time taken by any perfon, and to produce the original before the committee, or any jury who may be called on to decide any matter or difpute relating to the making or maintaining and ufing of the canal.

The engineer being now informed of the exact bounds within which the law has confined his operations, and of the feveral reftrictions or alterations that may have been impofed or made fince his former furveys, will, in all probability, find it neceffary to look over the line and all the propofed works again, accompanied by the intended refident engineers; and, in fuch revifal, it will be proper to divide the line of canal, and the feveral works thereof, into the neceffary number of parts, and to give concife and definite names to each, that are to be ufed in future, in contracts and bills, &c. of which diftinct parts or divifions a feparate account of the expences fhould be ftrictly kept by the refident engineer, the *overfeers*, or counters as they are generally called, (that the engineer is to recommend or employ upon the works) and by the office-clerks in a ledger, with proper heads for each length of canal, fet of locks, tunnel, embankment, deep-cutting, refervoir, aqueduct, or other great work, that may form a feparate divifion: fuch particular and divided accounts of the works will prove of the moft effential fervice to the committee, and to all others concerned, in informing and maturing their judgment on the actual or probable expence of every different kind of work; and will enable the committee to account to the proprietors how great, and fometimes unavoidable, as well as unexpected, expences may be incurred.

The committee fhould now well confider and inquire, whether any particular part of the line can be completed and opened with advantage, before the whole length can be got ready; and this being determined upon, the engineer fhould compare and confider, from the eftimates and particulars that he poffeffes, the comparative length of time that every particular work upon the length intended to be firft completed will require; and in this order, or with a proportionate exertion and number of men, fhould the feveral works be entered upon. Immediately after the plan has been fettled, preparations fhould be made for providing all neceffary utenfils and implements.

The Act for a canal fhould give the company and their fervants power to enter upon and occupy, for the temporary purpofes of their works, heaps of foil, &c. any land except parks, orchards, and gardens, within the limited diftance, on condition of their making a full and ample fatisfaction, by annual rent, to the former occupier or leffee, and for all damage to the owner and occupier, fo foon as the works are completed, and the heaps, &c. can be removed or levelled down, and covered with foil. The tunnels, deep-cuttings, embankments, or other great works, that are firft to be begun, (and the levels, widths, &c. of which we fuppofe to be completely fettled,) fhould be now marked upon the ground, with the neceffary allowance of width for the flopes, and the fpoil-banks, which the engineer may judge right to remain the permanent property of the company.

The land-furveyor fhould now proceed to treat, under the direction of the committee and the engineers, with the feveral parties who are entitled to the land that is wanted; for this purpofe, it will be right for the furveyor to prepare correct and explicit plans and admeafurements of every piece of land, and, in many inftances, to deliver copies of the fame to the parties; to confider well the intrinfic value of the land to the owner, and of any extrinfic or artificial value which it poffeffes, with ample allowance for the injury that his remaining property will fuftain by being detached, or by the fields being cut into inconvenient and aukward fhapes, or on any other account.

It is generally provided, in canal acts, that where any perfon's eftate is cut in two by the canal, and a part, confifting of lefs than a certain quantity, is fevered from the reft, the company fhall be compellable to purchafe fuch detached part, if the party wifhes it. And it ought to be provided, that the company are not to be obliged to make an occupation-bridge for lefs than a certain number of acres, unlefs the dwelling-houfe or farm-premifes of the eftate happen to ftand upon fuch fmall detached part.

As foon as the furveyor has made his contracts or fhort agreements with the parties, containing a full defcription of the lands or other property to be purchafed, the fame will probably be put by the committee into the hands of the clerk to the company, with directions for him to enquire into the nature of the titles of the parties, and prepare conveyances accordingly, in the fhort and fummary form that the Act ought to provide for fuch purpofe: in like manner,

where the parties who own the eſtate could not be come at, or have not been brought to agree by the ſurveyor, he ſhould furniſh the committee with the particulars of ſuch property, the price offered, and other particulars of the negotiation; in order that the clerk may be directed to prepare the neceſſary notices for a meeting of the commiſſioners deſcribed in the act, or a warrant to the ſheriff of the county for empanelling a jury to hear the evidence, who are to be ſummoned on the part of the company, and thoſe produced by the owner of the eſtate, and to view and examine the premiſes if neceſſary, and to give their verdict or aſſeſſment of the ſum that is to be paid by the company, and accepted by the parties.

The ground for the neceſſary reſervoirs, to ſupply the part of the line that is to be begun, ought to be among the firſt that is marked out, including ſpace for the head or new embankment that is to be made, and ſhould be treated for and purchaſed by the ſurveyor, and conveyed as above mentioned. The ground whereon the locks are to be built, or any wharf or walled baſons are to be made, ſhould alſo be carefully aſcertained by the engineer, and purchaſed in an early ſtage of the buſineſs, in order that the ſummer ſeaſons may be fully embraced, for the building of all the maſonry and brick-work.

The modern acts for canals uſually contain a clauſe, requiring all the top-ſoil to be removed. This, of courſe, will be attended to before any of the works are begun.

It has been found, from experience, that the banks of canals againſt which the water is to lie, ought, in general, to have their ſlopes ſo apportioned, that one foot in depth will give a horizontal baſe of one and a half foot; and to theſe or ſome proportions near them, rather above than below, as ſlopes of $1\frac{1}{2}$ to 1 are in general too ſmall, will the widths at top and bottom, and the depth of the intended canal probably be fixed by the engineer: and it has been found convenient and proper to make up the banks of canals one foot higher than the water is intended to ſtand in them.

We are now to ſuppoſe the reſident engineer to be proceeding with the ſetting out of the canal, being furniſhed with a map of the ſeveral fields through which it is to paſs, the line that is proviſionally ſettled for its courſe, but with liberty to deviate within certain limits therefrom, and with bench-marks which the engineer has left and deſcribed at certain diſtances, to regulate the top-water level, or height of the water in the intended canal; and, as above obſerved, one foot higher will be the level of the top-bank, or height of the banks.

It will be proper for this engineer, and we ſhall in future, for the ſake of diſtinction, denominate the other the *principal engineer*, to trace the levels accurately of each pound or level reach of the canal, and to put in level-pegs or ſmall ſtakes, at every two or three chains, more or leſs according as the ground is more or leſs undulating, as he proceeds; wherever the canal is conducted along the ſide of a hill, as will happen in a great portion of its length, the level-pegs are not to be placed exactly along the line that the principal engineer has marked out, but either above or below that line, as the ſlope of the hill may occaſion, exactly at that point in every place, where the level of the top-bank (traced by means of a good ſpirit-level, with teleſcopic ſights) cuts or interſects the ſurface of the hill. In ſome places it will be found that the principal engineer has drawn his line acroſs the point of a hill, ſo as to occaſion deeper cutting than uſual, to avoid going round it; or, on the contrary, croſſed a vale or low place, ſo as to require leſs cutting or perhaps none at all, to avoid taking a circuit up that vale to follow the level of the ground; and if either of theſe deviations ſhould be ſo conſiderable that the level-peg would fall more than two chains or thereabouts from the line, down or up the ſlope of the ground, the plan of having level-pegs upon the ſurface muſt be departed from, and holes ſhould, in the firſt caſe, be dug at proper diſtances in the line, and pegs put into the ſame with their tops to the right height; or, in the ſecond caſe, longer and ſtouter ſtakes ſhould be uſed, particularly in the fences that are croſſed by the line, or other places where they will not be liable to diſturbance, and drove firm into the ground till their tops mark the right level. In tracing theſe levels, the engineer will refer to and compare his work with all the bench-marks before deſcribed, and at each end of a level or reach, will level up and down to the bench-marks of the reach above and below the one he has been working at, and compare the ſame with the fall that the locks at each place are intended to have. And we recommend particularly to the engineer to be very punctual in entering minutely in his field-book the particulars and ſituations of the ſeveral level-pegs, and to make one or more of the men who aſſiſt him in levelling, perfectly acquainted with the ſituations and diſtinguiſhing marks of them, and frequently to cauſe them to be looked over and renewed; or continual repetitions of conſiderable lengths of the work will be neceſſary, owing to the diſturbance and loſs of the pegs by the cultivation of the fields and treading of the cattle, or by the interference of idle and miſchievous perſons of the country. Too much caution cannot ultimately be taken, by frequent reference to the bench-marks, with due allowance for any accidental variation that may have been diſcovered among them, and repetitions of the levelling, to avoid thoſe diſgraceful blunders into which ſome leſs capable and leſs careful engineers have fallen.

We are now to conſider, that the great *deſideratum* in canal digging is, that the ſtuff that is dug from one part of the work, ſhall, with the leaſt labour or diſtance of moving, exactly ſupply or form the banks that are to be raiſed in another; ſo that on the completion of the work, no ſpoil-banks or heaps of uſeleſs ſoil ſhall remain, or any ground be unneceſſarily rendered uſeleſs by excavations or pits. Six different caſes will be found frequently to occur in the cutting or forming of a canal. (*Plate I. Canal, figs.* 1, 2, 3, 4, 5, and 6.) A′A E L P P′ being, in every caſe, the line or ſurface of the ground acroſs the canal; A B C E, in the firſt five caſes, the bank on which the towing-path is to be made, and therefore generally the wideſt; L I K P in *figs.* 1, 2, and 5, the off or ſmaller bank; C I is the top, F G the bottom, and C F and I G the ſloping ſides of the canal, in every caſe. The bench or berm, I K, in *figs.* 3 and 6, is provided to retain and prevent the looſe earth that may moulder down from the upper bank P K from falling into the canal. Sometimes the interference of proprietors, or other cauſes, may occaſion the towing path to occupy the bank, or place of the bench I K, inſtead of B C, which will cauſe a conſiderable difference in the calculation or meaſure of the ſtuff to be moved in *figs.* 2, 3, and 5, but the ſame do not properly form new caſes. The firſt caſe occurs moſt frequently in cutting acroſs or along level meadows, and we were not ſo well able, when treating of the firſt ſurvey or projection of a canal, as we now are, to explain a limitation which ought to be attended to in all ſuch level-cutting, eſpecially if of any conſiderable length, viz. that the height or level of the canal ſhould be ſo contrived, that in any croſs ſection, as *fig.* 1. the ſum of the areas of A B C E and L I K P ſhall juſt be equal to E F G L, the part excavated or dug. It will readily be perceived that

figs. 4 and 6, are indeed other caſes of level cutting, occurring wherever the principal engineer has, in croſſing a vale, or point of a hill, found it neceſſary to preſerve his level above or below what would otherwiſe have been deſirable, if to be accompliſhed, as in our firſt caſe. The engineer will find abundant inſtances of *figs.* 1, 4, and 6, in all their degrees, and in a great portion of which there will either be a want of ſtuff to form the banks, as in *fig.* 4, or a redundancy from the deeper cutting, as in *fig.* 6, and the perfection of his ſkill will be ſhewn in ſo conducting the line, that every embankment, as *fig.* 4, ſhall have deep-cutting at both, or at leaſt at one of its ends, to furniſh the extra ſtuff, with the leaſt expence in moving it; in like manner, every deep-cutting, as *fig.* 6, ſhould have embankments at one or both of its ends, to receive the extra ſtuff. It is further evident, that the other three caſes, viz. *figs.* 2, 3, and 5, are but varieties of ſide-lying ground, or wherein the canal is conducted along the ſide or ſlope of a hill; and where it is evident, that a proper choice of the ſituation of the canal, higher up or lower down the hill, may occaſion A B C E and L I K P, the banking in *fig.* 2, together to be exactly equal to E F G L, the digging in this caſe; in like manner, where the ſlope of the hill is ſo conſiderable as to admit of no upper bank, as *fig.* 3, the bank A B C E may be equal to the cutting E F G I K P; it may be on a conſiderable ſlope that embanking is required, as in *fig.* 5, in order to preſerve the moſt direct line, or to reach any particular object; or deep-cutting may, and often does, occur in ſloping ground, and not in level, as we have ſhewn in *fig.* 6, but it ſeemed unneceſſary farther to multiply our caſes to delineate ſuch varieties. An attentive reader will find no difficulty in tracing every poſſible variation, by conſidering the line A′ P′, which repreſents the ground to vary in all degrees both of height and inclination, while the banks and canal, A B C F G I K P, remain fixed; and in this, almoſt the ſimpleſt inquiry that occurs in ſuch a work, it cannot fail of appearing, how eſſential a good knowledge of mathematics is to every engineer, and that none ought to be admitted to that honourable diſtinction, who are unlearned therein, however much they may have ſeen, or even executed, under the orders of abler men.

Our ſecond and third caſes requiring more than ordinary conſideration, before the line of the canal can be definitively ſettled, and the ground be marked out and purchaſed, unleſs waſte is committed, in purchaſing more than the company have occaſion for; we have repeated them again in *figs.* 7 and 8; and therein produced the lines of all the banks, by which the ſituation of the level-peg, of which we have ſpoken above, is ſhewn at a. It is alſo evident, that the lengths and poſitions of all the lines, B C, C F, F G, G I, and I K, being given, as alſo the poſitions of the lines B A, K P, and A′ P′; that the areas of the ſeveral triangles a B C, b F G, b C I, c I K, e F g, and e C K, and of the parallelogram I K g G, are known; and the calculation of theſe ſeveral triangles will generally, in practice, be very eaſy, from the conſideration of their being all ſimilar and iſoſceles. It is further evident, that the triangles a E A, b E L, c P L, b E e, and f E P, are in general ſimilar: from ſuch conſiderations, theorems can be deduced, ſhewing, in every caſe, the diſtances d L and d E of the ſlope-holes, or edges of the cutting L and E, *fig.* 7, from the level-peg d, or of d E and d P in *fig.* 8; as likewiſe the diſtances d I and d C of the top edges of the canal, meaſured upon the level, from the level-peg; ſo that the ſtuff to be dug may juſt form the banks. The diſtances d A and d P, *fig.* 7, and d A, *fig.* 8, that determine the points A and P, at which the banks are to be begun, are alſo eaſily deducible from the ſame conſiderations; and it is evident, that A P is the width of ground that ought to be purchaſed, except in ſuch caſes where a hedge may be neceſſary at P, or, as may ſometimes be adviſable, a hedge at the bottom of the ſlope at A, inſtead of its top B, when the neceſſary width for one or both of theſe hedges muſt be added to A P. The inveſtigation of theorems for the above purpoſes, and others which we ſhall have occaſion to mention, would lead us farther into the ſubject than would, perhaps, be proper, eſpecially as no perſon ought, in our opinion, to undertake or meddle with the direction of ſuch works, who is not only capable of uſing a theorem laid down by another, but of inveſtigating and preparing rules for every caſe that can occur, or be wanting in his own practice. We proceed, therefore, to adviſe the reſident engineer, on being furniſhed with the dimenſions that the canal and its banks are to have, to calculate tables for readily finding the diſtance d h of the level-peg from the middle of the canal, meaſured on the ſlope of the hill, let the hill ſlope with whatever angle it may; or rather, let the angle i d h, or depreſſion of the ſlope below the horizontal line i d, be what it may; and this will be moſt conveniently expreſſed, not in degrees, but by the natural ſines of the angle of the depreſſion; becauſe then, if a meaſuring chain of 100 links be laid down at length, upon the ſlope of the ground, and the difference of the level of its two ends be taken in links by the ſpirit-level, theſe will expreſs the two firſt figures of the natural ſines of the depreſſion, which is quite as great exactneſs as ſuch tables need be calculated to. The engineer will now proceed to put in a ſtake oppoſite to each level-peg, at the proper calculated diſtance down the ſlope, for the approximate or ſuppoſed middle line of the canal: theſe ſtakes will ſeldom be found for any conſiderable diſtance together, to range in a ſtraight or in any other regular line, that will be proper for the canal: and a very difficult and nice part of the engineer's duty is now to be performed, in ſtaking out a new line with a taller or a quite different ſet of ſtakes from thoſe formerly uſed, to avoid confuſion; this is called ſtaking the middle range of the canal. The requiſites in this new line or range for the centre of the canal is, that it ſhould as nearly coincide in every part with the ſtakes that were laſt put in by the calculation, as poſſible; that, where, in order to preſerve a regular and handſome line, and avoid the aukward, inconvenient, and unmeaning crooks and bends, with which too many of our canals, and even ſome of the lateſt conſtruction, are almoſt in every part diſgraced, the line is conducted higher than the calculated ſtakes for one or more ſtakes together, care muſt be taken that it ſhall quickly be conducted below others, ſo that the redundancy in cutting deeper into the hill in one place may be as exactly as poſſible balanced by a deficiency juſt by, owing to the line being conducted below the level-ſtakes. Beſides the conſideration above, it will be the time now to eſtimate and conſider the quantity of ſtuff that will be wanted to land up every bridge and lock, and to give extra thickneſs to the banks on which any toll-houſes, warehouſes, or other buildings, are to be erected, or trade carried on.

In narrow canals, or branches of that deſcription, it will be neceſſary to provide for wider places at ſhort intervals, for barges to turn, and to lie in while others paſs them; conſiderable ſkill and care are requiſite in the choice of proper places for ſuch purpoſe: they ought to be ſo ſituate that barge-men can mutually ſee each other approaching on narrow canals or branches, and provide for paſſing, without either of them having to drag their barge back again to a paſſing-place, as too often happens; at the ſame time, they

ought to be chosen, if possible, in such hollow or low places as will admit of widening the canal without much extra expence. Another consideration is, the excavation of basons, docks, or wharfs, from which stuff may accumulate, which ought to be used up, if possible, in embanking the line just by. Many canal companies have seen it their interest, on proper and timely application from land-owners, who were desirous of erecting wharfs, to direct their engineer to calculate upon, and to excavate the additional width necessary for such purpose, at the company's expence; this and the extra or deeper cutting that there must always be, in the approach to a lock on the lower side, and of embanking on the same approach on the upper side, should also be well considered and accurately calculated; and full and explicit memorandums ought to be entered in the engineer's field-book at the time, where the stuff was calculated to be had from for every embankment, and where the stuff is to be disposed of from every deeper cutting or extraordinary excavation. These memorandums will prove of the most important use in the revisal of the whole length of line or district that is about to be fixed; as also, in contracting for and letting of the work afterwards, by being able, without fear of mistake, to point out which way every part of the stuff is to be thrown or wheeled, as fast as it is dug, and that no part of the same may want moving a second time, or any wide or gouty places be made to disfigure the canal for finding stuff; or, what is often of more fatal consequence, the canal being dug deeper than usual for such purpose.

After the line shall have been thus marked out with the utmost care, it will still be prudent for the engineer to revise it again, and to make pretty accurate calculations of the quantity of stuff wanting, or to spare in particular places; in these kinds of calculations the engineer will find the most important aid in a ready use of the *slide-rule;* and we beg here to mention that a gentleman who has long distinguished himself by the various and important uses to which he has made the slide-rule subservient, has prepared a short but complete tract on its appplication in the concerns of an engineer, which it is hoped that he will ere long publish. Perhaps, on the review of the line, the curves or bends thereon may in some cases be eased, and beauty and convenience may be more fully attained without much, or often any extra expence. The *Droitwich* canal has been mentioned as one on which these points have been the most fully attended to. The portion of the canal that has been thus staked out and revised, may now have the boundary lines marked out of the land to be purchased; and the surveyor should proceed without delay to survey the same, and to treat with the owners for the purchase, as we have before mentioned. It will be among the first works to dig out for the foundations of the locks, if they are not already in hand, and for the bridges, if the season of the year and supply of bricks and work-men will admit of their proceeding immediately: the several drains or culverts that are to pass under the canal should also be dug out, and prepared for the masons or bricklayers, and the several safety-gates, stop-planks, weirs, and other erections, which we shall notice more particularly further on. It may be proper here to caution the engineer, that in case the pipes of any water-works, or that supply any gentleman's house, cross the line of the canal, such pipes should be laid at once, two or three feet beneath the bottom of the intended canal, with an easy descent and ascent therefrom, and the ground be made good again as soon as possible, both to prevent their being damaged in cutting the canal, and being exposed to frost, or to thieves, if of lead, by lying bare; and in case such pipes are found old or decayed, new ones of lead or cast iron should by all means be laid in the deep part under the canal. The top-soil should be carefully removed; and in order to determine readily and correctly the places of the slope-holes at E and L, *fig.* 7, and E and P, *fig.* 8, the engineer will find it useful to calculate the distances of d E and d L, and d P, by a general theorem, in terms of d h and h i, and to make tables for the several values of those data, that are likely to occur. The values of d P and d A, *fig.* 7, would be alike useful in a table for determining the limits of the banks that are to be raised.

Before cutting out the lock-spit, or small trench between the several slope-holes, as a guide to the men who are to dig, the engineer ought to cause holes to be dug in the line of the canal, near every second or third level-peg, or oftener, if the soil be variable, in order to prove the soil to a greater depth by two or three feet than the cutting of the canal is to extend; and each of these the engineer ought carefully to inspect, in order to determine what puddling or lining will be necessary; and what will be the difficulties of digging, owing to the hardness of the stuff, or to water that must be pumped out, &c.; all which circumstances, as well as the extra distance that any part of the stuff may require to be moved, must be well considered before the work can be let to the contractors or hag-masters.

The *puddling* or *lining* of a canal, to make it hold water, is a matter of the greatest importance, and we shall consider five cases, in *figs.* 9, 10, 11, 12, and 13, that are likely to occur or present themselves in the search, into the soil that is to be dug, by sinking holes as above mentioned: the first case we suppose to be that in which the whole is clay, loam, or other water-tight stuff, as shewn by the dark shading in *fig.* 9: all soils that will hold water, and not let it soak or percolate freely through them, are called water-tight. Our second case, *fig.* 10, is that in which the whole cutting will be in sand, gravel, loose or open rock, or any other matters that will let water easily through them, and such are called porous soils or stuff. The third case we suppose to have a thin stratum of water-tight stuff on the surface, shewn by the dark shading in *fig.* 11, and to have porous stuff for a considerable depth below, here distinguished by dots. The fourth case may have porous stuff near the surface, and water-tight stuff at the bottom of the canal, as in *fig.* 12. The fifth case is that where water-tight stuff appears on the surface, as *fig.* 13, below this a stratum of porous stuff, but having again water-tight stuff at no great distance below the intended bottom of the canal. The new raised banks that are left unshaded in all the five figures, are always to be considered as porous stuff, as indeed they will always prove at first, and in a great portion of soils they would ever remain so, unless either puddling or lining was applied; all ground that has been dug or disturbed must also be considered as porous. It should also be remarked that any kind of soil which is perforated much by worms or other insects, should in canal-digging be considered as porous stuff. *Puddle* is not, as some have attempted to describe it, a kind of thin earth mortar, *spread* on places intended to be secured, and suffered to be *quite dry* before another coat of it is applied; but it is a mass of earth reduced to a semifluid state by working and chopping it about with a spade, while water just in the proper quantity is applied, until the mass is rendered homogeneous, and so much condensed, that water cannot afterwards pass through it, or but very slowly. The best *puddling-stuff* is rather a lightish loam, with a mixture of coarse sand or fine gravel in it; very strong clay is unfit for it, on account of the great quantity of water which it will hold, and its disposition to shrink and crack as this escapes; vegetable mould or top-soil is very improper, on account of

the roots and other matters liable to decay and leave cavities in it, but more on account of the temptation that these afford to worms and moles to work into it, in search of their food: where puddling-stuff is not to be met with, containing a due mixture of sharp sand or rough small gravel stones, it is not unusual to procure such to mix with the loam, to prevent moles and rats from working in it; but no stones larger than about the size of musket bullets ought to be admitted. That the principal operation of puddling consists in consolidating the mass is, we think, evident, from the great condensation that takes place: it is not an uncommon case, where a ditch is dug, apparently in firm soil, that though great quantities of water are added during the operation, yet the soil that has been dug out will not more than two thirds fill up the ditch again, when properly worked as puddle. It should seem also, that puddle is rendered by that operation capable of holding a certain proportion of water with great obstinacy, and that it is more fit to hold than transmit water. It is so far from true, that puddle ought to be suffered to get quite dry, that it entirely spoils, when by exposure to the air it is too much dried; and many canals which have remained unfilled with water during a summer, after their puddling or lining has been done, have thereby become very leaky, owing to the cracks in the puddle-ditches and linings. One of the first cares of an engineer, when beginning to cut a canal, is to discover whether good puddling-stuff is in plenty, and if it be not, it must be sought for and carefully wheeled out or reserved wherever any is found in the digging; or perhaps procured at considerable distances from the line, and brought to it in carts. It has happened in some stone brach or loose rocky soils, that all the puddling-stuff for several miles of the line, required to be brought to it; but even this expence, serious as it may be, ought not to induce the copying of those, who have left miles of such banks without any puddling, and have made a winter canal, but which no stream of water that is to be procured can keep full in the summer months. It is usual in canal acts to insert a clause for the security of the land-owners, to require the company to cause all the banks that need it to be secured by puddling, to prevent damage to the land below by leakage: and it would have been well for all parties in many instances, if this clause had been enforced. It appears that the Dutch have been in the habit of making mud-ditches to secure the banks of their canals and embankments, from time immemorial; and that operations similar to our puddling have been long known on the continent, but it is not clear at what period it was introduced into this country; we think that the fens of Cambridgeshire and Lincolnshire, in which so many works have at different times been executed by Dutchmen, are the most likely places in which to search for early evidence of it's use. We cannot think that *James Brindley* was the first who ever used it in this country, although we might admit that the *Bridgewater*'s canal was the first in which it was systematically used as at the present day. If we compare our first, fourth, and fifth cases, *figs.* 9, 12, and 13, we shall find in all of them a water-tight stratum as the basis; and the practice in these cases is to make a wall of puddle, called a puddle-ditch, or puddle-gutter, within the bank of the canal, as shewn in section, by *a c*, in the above figures; these puddle-gutters are usually about three feet wide, and should enter about a foot into the water-tight stuff, on which they are always to be begun: and they should be carried up as the work proceeds to the height of the top-water line, or a few inches higher. Our second and third cases, *figs.* 10 and 11, evidently will not admit of the above mode, because we have here no water-tight stratum on which to begin a puddle-gutter as a bottom: in these cases, therefore, it is usual to apply a lining of puddle to the sides and bottom of the canal, as shewn by the cross shading in *figs.* 10 and 11: the process of puddling and lining will occur more properly further on, as we proceed in describing the operations of digging and forming the canal.

In order to describe more intelligibly the process of setting out and digging a canal, in the two cases where *puddling* or *lining* will be requisite, we have repeated our first and second case, but on a larger scale, in *figs.* 14 and 15; wherein *p* is intended to represent the hole that has been before supposed to be sunk, in order to prove the soil; and, according as this terminates in water-tight or porous stuff at its bottom, that puddle-ditches, *q e s w* and *x e f t*, *fig.* 14, or a lining, *q r s t* H G F D, *fig.* 15, is to be applied; D H being the height to which the water is to stand in the canal. The engineer will in the first case determine the place of E and L on the ground, and dig small holes or nicks to mark the same, called slope-holes; but in the second case other marks must be made at *u* and *v* about five feet from the former, to direct the beginning of the cuttings, with allowance for the lining. A skilful and very handy workman is now required to mark out the line upon the ground, called the lock-spit, between the slope-holes at E, *fig.* 14, above-mentioned, which we have supposed to be made at about two or three chains from each other. This is done by laying down and stretching a strong line upon the ground, between two or more adjoining slope-holes, and if the canal is not to be straight in that part, with small pegs to give it the gradual and regular bend in every part that the canal is to have; the workman then proceeds, holding his spade or grafting tool not upright, but always with the slope C E, that the bank of the canal is to have, and strikes it successively into the ground close to his line, until the whole length of the line is marked out; by this means, if the ground has sudden undulations, or hollows, as continually happens, owing to the ridges and furrows of cultivated lands, and other causes, yet a regular line coinciding in every part with E is marked out upon the surface; before the line is taken up, another labourer follows on the other side of it, and strikes in his tool inclining the contrary way, by which a triangular sod or piece of earth is cut and thrown out: a similar lock-spit must be cut on the other side of the canal at L; and the same at *u* and *v* in *fig.* 15. If neatness and regularity are properly consulted, lock-spits for the extremities of the banks at A and P will also be proper, especially if the land A A′ and P P′ is valuable, and the damage by the scattering and laying of the stuff would be considerable. The engineer has now to determine, in *fig.* 14, the points *c* and *d* for the beginning of the puddle-ditches, and these he ought to chuse such, that if the same were carried upright to the top-bank, *b* C or I *a* would be about one foot: if this is not strictly attended to, the labourers or navigators, as they are called, will for their own convenience begin their puddle-ditch much too near the canal at E and L in some cases, and not make it upright but hatching back to arrive at *a b*; and puddle-ditches so made are apt, owing to the settling of the bank, to get broken and be spoiled. It may be proper here to remark, that canals set out with the scientific precautions and care that we have recommended, will always have the proper quantity of stuff to allow for the settlement of the banks, because A B C E + L I K P = E F G L, in the same settled or consolidated state, that the latter part was before the digging commenced: it will, however, be proper to give the contractors a table or rule shewing, according to the height, as *a c*, what extra height a suddenly raised bank is required to be, to allow for settling: and it is evident that

the slopes of such banks must be steeper in the first instance, than they are intended ultimately to be.

We may now suppose the engineer to proceed to the letting of the cutting of certain lengths of the canal to contractors or bag-masters, who will employ a number of navigators under them, in digging and puddling the canal. It is usual to let the work at a certain price per cubic yard of digging, and to pay for the puddling and lining either at a certain price per cubic yard, or per yard run of the canal. The engineer ought to inform himself thoroughly on the difficulties and facilities which attend the work he is about to let, and to draw up a short but explicit contract to be signed by the contractor. We cannot but recommend that all contracts for material or large jobs of work, not only in cutting, but for the mason's, and other works in particular, should be submitted to the principal engineer for his approbation, before they are signed or finally concluded on. The prices allowed ought to be fair and liberal, according to the circumstances, so that the contractor may have no pretence on account of low prices, to slight his work, particularly the puddling; and they ought in every instance to be strictly looked after, and made to undo and renew immediately, any work that shall be found improperly performed. We recommend it to the engineer to keep a strict account, by means of his overseers or counters, of all the men's time that are employed upon the works; distinguishing particularly the number upon each work, and whether employed by the day, under the company, or upon the work that is let to contractors. These particulars are most essential towards knowing, what money ought to be advanced to the contractor during the progress of his job, and towards informing and maturing the judgment of the engineer, in the length of time that a certain number of men will be in performing any future work that he may have to direct; and a calculation ought to be made in every instance of the day-work, and compared with the contract price, by which alone a correct judgment can be formed of the proper prices at which work ought afterwards to be let, so that the labourers may receive proper wages, proportionate to their exertions, and the contractor be amply paid for his time, skill, and superintendance; and yet economy and the interest of the company be duly consulted. Barrows and wheeling-planks, horsing-blocks, and other implements, are generally found by the company; and it is usual to consider 20 to 25 yards, to be a stage of wheeling, and a price per cubic yard to be fixed, according to the number of stages that soil is to be moved: where this distance exceeds 100 yards, it will not often be eligible to perform it by wheel-barrows; and runs of planks with an easy descent, if the same is practicable, should be then laid for large two-wheeled barrows, or trucks to be used thereon.

The cutting of a canal being let, the work is usually commenced by a labourer, on the part E *g*, *fig.* 14 or 15, on the lower side of the canal; and from the lock-spit at E he marks out a certain width to *g*, such that he can throw or cast the stuff as he digs it, on to the part A *c*, and so that the heap may not obstruct the intended puddle-gutter *c d*. The side E F he is careful to cut down in the proper slope of the bank; the other side is usually cut straight down, and this work is continued until he comes to the bottom of the intended canal at F *h*, and this space E F *h g* is called the "reaching." The same process is followed on the lower side of parts that want lining, as *fig.* 15, except that *n r h g* is the reaching in this case, and that there is no necessity to throw the stuff further in this case, than that it may lie upon *n* A without rolling back into the work; and it is usual, if the reaching will not be very deep, to lay two or three rows of sods or sound spits of earth, with regularity in the face of the slope *n q* to form part of the bank, and to throw the other stuff over these. Reachings are also to be dug on the upper side of the canal, as *i k* G L, or at least as much stuff is to be thrown out therefrom as can conveniently be stowed upon *d* P and *v* P, *figs.* 14 and 15.

It is now time to commence the puddling in *fig.* 14, and a labourer begins by digging out the bottom of the intended puddle ditch *c e f d*; if the soil dug out is good puddling-stuff, he lays it on the part *d* E, if otherwise he throws it at once on to the heap on A *c*. A careful examination of the face E F of the reaching will shew to what depth the puddle-ditch *d f* ought to be carried in every part, to reach and intersect any faulty places, or veins of lighter soil, or worm, rat, or mole-holes that may accidentally occur in the bank. After the puddle-ditch is dug clean out to its proper depth, and this is a circumstance that the engineer or some careful overseer ought always to look particularly to, about 9 or 10 inches thereof is to be filled loosely up with puddling-stuff, either from that which comes out, or from the nearest heap in reserve, all large stones, sticks, straws, or other extraneous matters being carefully picked out as the stuff is sprinkled in: by this time, unless the season is very dry, it is probable that some water will be collected in the bottom of the reaching F *h*, and this should be laded out with a scoop into the puddle-ditch, so as to give the stuff therein a good wetting; if the puddling-stuff be of the stiffer kind, or was very dry, it will be right for the labourer to betake himself to some other part of the work for two or three hours, but perhaps giving his stuff another sprinkling of water in the interim; he may then proceed with the puddling; and for this purpose he ought to be provided with a stout pair of puddling-boots, that will keep out water; he begins at one end of the trench, and keeps chopping with his tool into the stuff and quite through it, giving his tool a lunging motion every time before it is withdrawn, so as to let the water into and to stir every part of the puddling-stuff; if more water is wanted, another labourer is set to lade it out of the reaching as before; and the puddler thus proceeds, chopping down at every inch or thereabouts as he slowly advances, and trampling about at the same time as much as he can with his feet, which greatly assists the operation: when arrived at the end of the trench, he returns and repeats the same operation, until every part of the puddle is properly worked; which is known by the tool going equally easy into it in every part, which it would not do if any dry lumps remained, and the whole being in a semifluid state; giving the puddling-stuff just the due quantity of water is very essential to its working well, and this, experience will soon point out.

Very great care and management will, in general, be required on the part of the engineer, to furnish water for the puddling: it will often require to be brought in temporary trenches, perhaps across several fields from some mill-dam, large pond, or spring of water above the canal; for which purpose general powers ought to be given in the act, upon condition of levelling and making all such trenches good again as soon as possible, and paying for the damage; often times puddling water is not to be had without pumping it up, and conveying it considerable distances in troughs, of which great numbers will be required. It will very often be requisite to convey the water across the canal in troughs to the different puddle gutters, and plenty of trestles should be in readiness for supporting these troughs at the requisite heights. Considerable care will be necessary to turn off the surplus water, into some channel where it can run off without flooding the works; or to stop it at its source; this last ought always to be adopted, when the supply is not very

plentiful, or the owner of the ftream or pond might be injured by taking a conftant ftream from him, during the progrefs of the work. The firft or bottom courfe of puddle being properly worked as above, it fhould then be fuffered to ftand two or three days undifturbed, and without any more water being given to it; when it will be found fufficiently fet that a man may ftep on to it without finking in; it is then ready to receive a fecond courfe; the firft ftep is to fcrape off and remove any lumps of earth, ftones, fticks, or other matter which may have fallen into the puddle-ditch; about 10 inches thick of puddling ftuff is then to be fprinkled lightly into the ditch as before; and water is to be applied either from the reaching, or from fome of the troughs which we have been mentioning: fome hours time is to be allowed for the ftuff to foak, unlefs it be light loam, and moift at the time of putting it into the ditch; in fuch cafe, the puddling may be begun almoft immediately: care muft be taken that the tool be made to penetrate a fmall diftance into the old puddle at every chop, in order that the two courfes or layers may be properly incorporated. After this coufe is properly wetted and worked, it muft ftand the proper time to fet as before, but by no means to get dry, otherwife it will be found full of cracks and muft be worked anew: and in cafe, owing to any temporary fufpenfion of the work, it fhould be neceffary to leave a puddle-ditch before it is finifhed, it ought always to be covered, and left with a dry or unworked courfe of puddling-ftuff upon it, to keep the air from it, and preferve the proper moifture in it.

When a fufficient number of courfes of puddle have been added, to fill up the ditch *c e f d*, two or three rows or courfes of fods, or fpits of earth, muft be laid on each fide, to raife the ditch fo much higher; at the fame time that the heap of ftuff on A *c* is levelled down, and other ftuff is brought by the men, who are wheeling from the bulk *g h k i* that is left in the middle of the canal, and laid on *d* E to back up the fpits or fods: after cleaning the furface of the puddle, if properly fet, it will be ready to receive another courfe of puddling-ftuff, the water muft be turned on, it muft have time to foak, if neceffary, and then be worked and ftand to fet as before: other rows of fpits of earth may then be laid, to raife the fides of the puddle-ditch, and the bank may be made up to the fame height by frefh ftuff wheeled in from the canal; and care being taken to lay fpits of earth to form the flopes A B, and E C, as the works proceed upwards, particularly the infide flope C E, which fhould be well trod and confolidated by ftrokes of the tool to prevent its falling down, or being difturbed by the water when the canal is filled; another courfe of puddling-ftuff is then to be added, and all the fame procefs gone through till the puddle has arrived at *q w*, the height of top-water, or an inch or two higher, which being properly fet, the bank is to be made up, covering the puddle completely up with common ftuff, to the intended height of the top-bank B C, with proper allowance for the fettling; and obferving that the puddle will not fettle near fo much as the other ftuff, if at all. The procefs is no way different, by which the other bank L I K P, and its puddle ditch, are to be carried up, and completed to the intended height. The part of the canal, with puddle-gutters, *fig.* 14, of which we have been fpeaking, has, in general, a lump or ridge of ftuff remaining in the middle of its bottom, until the very laft: a different fyftem ought, however, to be purfued with fuch parts, *fig.* 15, as require to be lined; here the banks AB *q n*, and *v t* K P may be at once made up, and the whole of the fpace *n r s v* ought to be cleared for certain diftances, before the lining of the bottom can be begun. A great deal of management is required by the overfeer or contractor, to manage all thefe parts of their bufinefs, fo that there is no hindrance of any part of the work, that every man is provided with ftuff by the wheelers, when he wants it to make up his banks or to puddle, and that the parts to be lined are cleared in time. To accomplifh all thefe objects, a good part of the ftuff cannot be wheeled directly out to the neareft or oppofite points of the bank, but it muft be worked forwards and backwards obliquely, on the runs of wheeling planks by the wheelers, as occafion may require. It may often be neceffary to exceed one or two, or perhaps more, ftages of wheeling, to avoid taking out the ftuff and clamping it, by which it would require filling again, damage would, in moft cafes, be incurred on the adjoining lands, and frequently the puddling and working of the banks would be impeded, by croffing them to land the ftuff.

A length of the canal that is to be *lined* being cleared, and the bottom levelled and cleaned fmooth down to the line *r s*, a courfe of puddling-ftuff about 10 or 12 inches in thicknefs is to be fpread over it, with all the precautions, to extract extraneous and hurtful matters, which have been before given, and the whole is to be wetted and allowed to foak if neceffary, as before: the working of this puddle is now to be begun; and as the extent will generally be large, feveral men may be employed, at once, upon it, fo as to make it worth while for an overfeer employed by the company, to attend them conftantly to fee that no part of the work is flighted: as the bottom in this cafe is fuppofed to be fand, loofe ruble of a rock, chalk, or other matters, that would injure the puddle if mixed therewith, we have recommended a thicker courfe at firft than is ufual of puddling-ftuff, and in working the fame the men ought not to ftrike their tools deeper or even quite fo deep as the bottom of the puddling-ftuff to avoid difturbing the bottom. When this courfe of puddle has been allowed to fet, another courfe of about nine inches is to be added, and treated as before, till about three feet of puddle is added, if the foil is very porous; and the top courfe being fet, a courfe 18 inches or two feet thick of the common foil or ftuff fhould be laid evenly upon it and the bottom levelled; this covering of the bottom fhould be rather dry, and not in large lumps, or with great ftones or fticks in it.

The *lining of the fides* is now to be proceeded with as follows; the top covering of the bottom fhould be removed for three feet in width next each of the floping banks; and the furface of the puddle be carefully cleared of dry lumps, ftones, &c.; a thicknefs of nine inches of good puddling-ftuff is now to be laid in this place and wetted and worked, and allowed to fet as before directed, when another nine inches is to be added in like manner; fome common ftuff from the digging of the canal is then to be brought in fpits or fods, and carefully piled up for two feet in width, and about nine inches in height, hatching-back before and behind, agreeable to the flopes F E and G L, and leaving a fpace or puddle-ditch behind, next to the fides *r n*, and *s v*; the furface of the puddle at the bottom of thefe is to be carefully cleared, nine inches of puddling-ftuff applied, wetted, worked, and allowed to fet as before: more fpits or fods are then to be piled in the front, as a facing to keep up the puddle, and their interftices fhould be filled with fine ftuff to make the whole folid; when puddling-ftuff is again to be applied behind, and the fame procefs repeated till the puddle and facing arrive at *q* D and H *t*, when the remainder is to be made up with dry ftuff and fpits to the top-bank level at C and I, as directed in the former cafe.

The laft of thefe ways of making a canal water-tight is the more tedious and expenfive of the two; it is however general, and may be applied in any fituation with perfect

ſucceſs. Mr. *Thomas Telford*, in *Plymley's Agricultural Report of Shropſhire*, 8vo. p. 295, when ſpeaking of the *Shropſhire* canal, ſays, "This canal, carried over high and rugged ground, along banks of ſlipping loam, over old coal-mines, and over where coal-mines and iron-ſtone are now actually worked under it, is a ſatisfactory proof that there is ſcarcely any ground ſo difficult but where, with proper exertions and care, a convenient water conveyance may always be obtained." And we have heard of inſtances of canals being conducted over ground ſo rocky, and abounding with ſuch great chaſms, and looſe pieces of rock, that many yards together of the canal bottom might have fallen in, had not the precaution been firſt taken, of removing all the ſmaller and looſe ſtones and rubbiſh, and wedging in the large looſe pieces of rock with ſtones, ſet in mortar, and thus rendering the foundation ſound, on which ſoil to fill up the inequalities, and a lining and facing was applied as above, with perfect ſucceſs. We have already obſerved, that ſome perſons have thought it right to omit puddling or lining, where ſprings appeared in the bank of a canal; and the matter is of ſo much conſequence, that we beg farther to obſerve, that the appearance or non-appearance of ſprings ought in general to have no effect in determining the propriety of theſe eſſential meaſures; if a ſpring is of any uſe to a canal it will riſe, owing to the puddle-ditch or lining, and run over the ſame into the canal, and no water will be thereby loſt; and if it will not ſo riſe, it may ſafely be ranked as a drain of the moſt miſchievous kind, inſtead of a ſupply, and therefore very eſſential to be ſtopped up.

In caſe it is found that there is ſtuff to ſpare after completing the banks, it will ſometimes be adviſable to remove the top-ſoil from A′ A in low places, and after ſpreading the extra ſtuff ſo as to make the ground good, to return and ſpread the ſoil upon it: the part P P′ will often admit of ſimilar treatment, and ſometimes ſudden hollows there may be filled up, ſo as to have a fall to the top-bank I K, and avoid a deep ditch through an adjoining ſwell or riſe of the ground at P, to carry off the rain water to a culvert where it is to paſs under the canal: where it happens that P P′ is waſte or ground of little value, or the company is poſſeſſed of a piece that they have been obliged to purchaſe and cannot readily diſpoſe of, it may be proper to make a heap or ſpoil-bank of any extra-ſtuff, to be afterwards boated away as occaſion may require. If a deficiency of ſtuff is experienced to complete the banks, the part P P′ furniſhes a good reſource in many inſtances; the top ſoil being removed on the higher parts, an excavation like P *y* P′, *fig.* 14 and 15, may, and indeed muſt in many inſtances, be made with a proper fall for conveying the rain-water that falls in every part above the canal to the brook or culvert that is to take it off; the ſlope P″ *y* ought to be ſo eaſy, and the top-ſoil ſo ſpread, that the land ſhall be as fit for agricultural purpoſes afterwards as before. Another reſource ought in an earlier ſtage of the buſineſs to be provided, in the deep-cutting, by marking out a yard or two or more width of ground to be purchaſed on the upper or deeper ſide, than is actually wanted, by which a great deal of ſtuff may be procured at a comparatively ſmall expence of land: it muſt be evident, that the reſources we have pointed out above are inadequate to receive any great redundancy, or to ſupply any great deficiencies of ſtuff, and are only ſufficient where the canal has been ſet out with ſcrupulous care; bungling, or careleſs canal-makers muſt be content to leave laſting marks of their incapacity or folly behind them, in the many ſudden bends into the hill that they are obliged to make to obtain ſtuff, and out of it to diſpoſe of the ſame in other places, with numerous wider or deeper places on the canal to make up the banks, or in enormous ſpoil-banks or uſeleſs excavations. Where a reſerve of ſtuff has been made in the deep-cuttings at ſeveral points on each level or reach of a canal, as above-mentioned, it will be the better fault of the two, to experience a deficiency of ſtuff; becauſe as ſoon as the bottom of the canal has been cleared, and the lining of the bottom and ſides for ſome height performed, or the puddle-ditches carried up, the canal may have 18 inches or 2 feet of water let into it, and dirt-boats may be uſed to carry ſtuff from the deep cuttings to make up the banks in other places; whereas all redundant or ſpare ſtuff muſt be got out before the bottom lining can be applied, or any effectual uſe made of boats to move ſtuff from place to place; and the ſame advantages will be experienced in ſituations where puddling-ſtuff is only to be procured at particular points on the line, by clearing out and completing the bottom part of the canal for conſiderable lengths, ſo that dirt-boats may be uſed to bring the ſame for the puddling or lining of the upper part of the banks, which, if there is ſpare ſtuff, cannot be effected without heavy expences in moving the ſame and forming ſpoil-banks. Where the line of a canal is to croſs an extenſive ſtratum of valuable brick earth, or one of good gravel for making of roads, it will often be adviſable, eſpecially if the line can be rendered more direct thereby, when ſetting out the canal, to cut pretty deep into ſuch materials, and even quite through the gravel, if the ſame is practicable, as might have been done at Dawley-deep, between Paddington and Uxbridge, on the *Grand-Junction* canal; for although conſiderable expence will in the firſt inſtance be incurred in digging and in damage for ſpoil-banks, yet ſuch materials, as good brick-earth and gravel, will in almoſt every inſtance find a market as ſoon as the canal is opened; ſuch a ſituation of the canal may prove of eſſential ſervice to its trade, by enabling the adjoining proprietors to work the whole thickneſs of their brick-earth, gravel, or other uſeful matters, and deſtroy but very little of the ſurface of the ground, and without being annoyed by water, but which the canal would catch in very conſiderable quantities perhaps, inſtead of loſing water by preſerving a high level through porous ſtuff. It is highly to the intereſt of a canal-company to give facility to the getting and conveyance of all uſeful articles within their diſtrict, at the cheapeſt poſſible rates, as the only means of opening new ſources of trade or manufactures, by which their concern will be in the moſt eſſential degree benefitted. In diſtricts where ſtone and gravel for making and repairing of roads are ſcarce, it will be proper to pay the labourers certain rates per cubic yard for all the ſtones or gravel that they may collect out during the work, and ſtack in proper places; as reſources for the making of the towing-path C *l*, *fig.* 15, and for making good the landing or aſcent to the ſeveral bridges, and the ſeveral pieces of new road that the engineer will have to form, near to the canal and bridges; the lock-banks and all wharfs and landing places ſhould alſo be covered with good gravel to render them ſafe and convenient for uſe: if good gravel can in places be interſected in deep-cuttings, much of the above expence, as well as of cartage, may be ſaved, by an early uſe of dirt-boats in the bottom of the canal. It cannot, we think, have failed to ſtrike every reader ere this, how very important and various the duties of the reſident engineer are; but the ſame will be much more apparent, when we ſhall have finiſhed, in the following pages, the more particular obſervations that occur to us under the heads of reſervoirs, feeders, aqueducts, embankments, culverts, ſafety-gates, weirs, tunnels, deep-cuttings, locks, ſubſtitutes for locks, inclined planes, rail-ways, bridges, towing-paths, fences, drains, boats, towing or mov-

ing boats and trams, cranes and implements, &c. of which we shall proceed to treat; after observing, that none but men of the strictest integrity and extensive knowledge ought to be employed as resident engineers, and that the committee and principal engineer ought not to hesitate in offering and paying such men a very liberal salary, to engage the whole of their time; and, that too great a length of line or extent of business should not be put upon such a man. This is the proper sphere, where young men or others, of knowledge and persevering industry, who are coming forwards in their profession, should exercise and give specimens of their abilities as engineers; and it will prove of the utmost importance to such, as well as to a company who have an extensive line of canal to construct, to employ more than one of such men at the same time, upon adjoining lengths of the canal; where their emulation may be excited in an honourable contest, as to those who shall execute their portion of business in the most complete, orderly, and economical manner.

One of the first considerations relating to the *construction* of *a Reservoir* for supplying a canal, is the supply of water that is to be expected for it, and in what proportions at different times of the year: for this purpose we suppose the engineer to be furnished with an accurate survey of the vale or vales that lie above the intended reservoir, so as to be able to calculate exactly, how many square miles and fractions of surface drain towards or vent their rain-water through the part intended to be embanked for the reservoir; it will be very proper also to be furnished, if possible, with the exact gauge or quantity of water that has actually in former years been discharged by the brook or stream that is to be embanked; as also with the quantity or depth of rain which usually falls within the drainage of the intended reservoir. If the length of time that has elapsed, since the situation of the reservoir has been determined on, has not allowed of careful and accurate experiments being made on these points, the engineer must assume them from the best data that the information of millers and other persons will afford, and the printed tables, or journals of rain, kept by curious persons in the nearest similar situations, must be consulted: it is particularly necessary to attend to this last circumstance, because there are, we believe, instances of places where the annual depth of rain does not amount to a foot, and others in which it exceeds five feet; while 23 inches is about the medium depth of rain annually, at or near London. The most perfect method of obtaining true information on this subject, is to gauge the different springs or streams, from whence the supplies of water are to be derived, and thus to ascertain the exact surplus, after the mills are amply furnished. In the great contest about the Rochdale canal, Mr. Rennie had all the streams, which could be affected by the proposed reservoirs, gauged for about a year. He first ascertained the state of these streams at a time when the mills were amply supplied with water, and had proper gauges fixed upon them. The daily difference was measured, and the surplus thus ascertained amounted in the year 1793 to sixteen times the ordinary produce of the rivers. The evaporation that takes place, from a given surface of water in different places, has not yet been so accurately observed as the importance of the subject to canal engineers deserves: *Mr. Bevan's* observations thereon, at Leighton-Buzard in Bedfordshire, continued for five years, to the end of 1804, gave an evaporation of 22.92 inches at a medium per annum, while the depth of rain there, in the same period, was observed to average 23.28 inches; in some years the evaporation considerably exceeded the depth of rain, and in others it fell as much short of it or more. On this subject, see the article Evaporation.

It will sometimes happen, that the valley in which the reservoir is to be made, has other valleys parallel to it, on one or both of its sides, such, that by beginning a sough or small tunnel above the level of the reservoir, continuing it with a small rise through the adjoining hill, and from its further end continuing a ditch or feeder along the side of the hill rising gently as it proceeds till it intersects the bottom of the vale, a brook or considerable stream of water may at times be there intersected and brought into the reservoir; or, another case may happen, in which the adjoining valleys instead of being parallel to, proceed directly from the reservoir valley, and yet feeders may be set out, so as to collect great quantities of rain and spring water, from the sides of the hills that slope towards the adjoining valleys, and through which it would otherwise escape. Both these methods we saw successfully practised about the year 1796, for increasing the supply to the new water-meadows which the late *Duke of Bedford* had directed his agent to construct near Woburn. A parallel valley, which crosses the turnpike road at about $43\frac{1}{8}$ miles from London, has its stream of water diverted at that point, and through a short tunnel into the Woburn vale, which it otherwise would not have reached for a mile or more, and at a much lower level. From the lowest point in the ridge of high land that separates the Woburn vale from one that proceeds through Potsgrave parish towards Leighton, a trench or feeder was begun, and carried for a mile or more along the side of the hill in Potsgrave, by which the rain water of 3 or 400 acres of land was brought into a reservoir in a branch of the Woburn vale, to be reserved for use.

The engineer, who has well considered and ascertained all the circumstances of the vales in or near to which his reservoir is to be constructed, will be able, by help of a number of levels, carried round to where the surface of the water will extend at every 5, 10, 15, 20, &c. feet in depth, or oftener, if the nature of the ground requires it, to calculate to what height the head of the intended reservoir must be embanked to retain all the water that his vallies can supply, between the times that it is fed by rains and springs, and required to be let off to the canal or mills, or such quantity only as it may be necessary so to retain, according to the principles before laid down.

The necessary height of the head or embankment for a reservoir being determined, the next step will be to examine minutely the nature of the strata and soil that are to be covered with water, and whether the whole or any part of the same is so porous as to require lining with puddle, as also the nature of the stuff which is to be used in forming the head or bank, as thereon will depend, in a great measure, the degree of slope which the banks ought to have; $1\frac{1}{2}$ to 2 feet base to one in height seems the usual slope; but if the soil should prove a slippery clay, as at the Aldenham reservoir, belonging to the *Grand Junction* canal, a greater slope should be given, as well as the precaution taken, of putting in frequent layers of sand or coarse gravel, to lessen the tendency of such soil to slip. If the reservoir will require bottom lining, yet still it will not sometimes be right to trust to lining for the head of the reservoir, but to carry up a puddle-ditch in the centre of the head, because if the inside of the head should happen to slip, the lining would be broken and disturbed. The slopes being settled, it will be right to make a cross section of the valley at the place of the centre of the head, as A C B (*Plate I. Canals, fig.* 16.) and to determine by levelling, and mark out the places of, as many perpendiculars or equidistant ordinates a, b, c, &c. as the width of the head and the nature of the sides of the hills A C and

C B may require; we are next to consider, that the section of the intended bank at every one of the points a, b, c, &c. will be nearly triangular, as D G F, *fig.* 17. (except wanting a small triangle G H I at top) K E being equal to the ordinate *a*, *b*, *c*, &c. in every case; the base D F, or width of the head at the different places, varying according to the height K E, and according to the inclination or fall of the ground D F, compared with the horizontal lines F I. and I H. A theorem for E D and E F will readily be obtained with the above data, and these distances being calculated and laid off on the ground, so many points for the bottom of the slopes will be determined, and a careful workman will find no difficulty, by pegging down his line and holding his grafting-tool in the inclining position H D and I F, (as before mentioned respecting marking out the canal) to mark out a lock-spit, as a boundary or base for the intended embankment.

If the several triangular sections D G F are taken near enough to each other, A *a*. *ab*, *bc*, &c. and are carefully calculated (for which purpose in very large works, tables framed from the theorem will be found the readiest way), by deducting a triangular prism, whose base is H G I, and length A B, *figs.* 16 and 17, the solid contents of the required bank will be very exactly obtained; and the most eligible spots for obtaining that quantity of stuff, as near as may be, without endangering the slipping or stability of the bank, may be marked out; and the work will then be in a state to be let to the contractors who are to execute it. But before this is begun, it will be necessary to provide for the escape of the surplus water when the reservoir shall be full, as also for letting out the water for use; for these purposes an arch of brick-work, or of stone, may be begun at the lower limit of the bank in the lowest ground or brook course, as at D, in *fig.* 18, and continuing the same on a level to a point M, some distance within the head D H I E of the reservoir; D′ L′ being the lowest ground or longitudinal section of the valley. This arch should be high enough for a plank to be supported and fixed on irons or bearers across it, about a foot from its bottom, on which a man can conveniently walk along; and, for this purpose, the arch had better be made elliptical, or higher than it is wide; a secure iron gate should also be provided, to be kept locked at a few yards into the arch from D, for excluding improper persons. At the termination of the level arch at M, there should be a circular well of 6 or 8 feet diameter more or less, according to the greatness of the floods that may be expected, to be sunk 6 or 7 feet deeper than the arch D M; its bottom should be formed either of one very large flat stone, or of a few well jointed ones laid on a course of puddle, and on this the steining of the well should be begun, with bricks of the very best quality, well keyed up and embedded in cement; and having a course of puddle of 9 inches or a foot thick, worked all round behind them, allowing the same to set as the work advances in height; this well, and the arch D M, are to be securely groined into each other at M; near to this groin, or within reach of a man standing on the end of the plank above mentioned, which should not advance quite up to the well, should be a large brass cock worked into the walling; the mouth of this cock should be turned down, so as to discharge its stream of water exactly in the direction for the centre of the bottom of the well; and from the cock should proceed a large pipe of lead or cast iron behind the wall of the well at some distance, for which purpose it will require a considerable bend, and this pipe should proceed, soundly embedded in good puddle, towards a convenient place as S, in the bottom of the reservoir, where it should terminate under a large and stout box full of holes, or a fine grating, to prevent the entrance of fish or any thing that might choak the pipe or cock. In constructing the arch before mentioned, after it has proceeded from D as far as the intended puddle-ditch *c d*; the puddle-ditch should be dug out for some distance on each side across the arch; the same should be continued down to water-tight stuff, or at least for some depth into other matter, if unfortunately such is not within reach; and, when the puddle is carried up and set, as also a course of puddle in the bottom of the arch course *d* M, which should have been dug deeper for such purpose; the bottom of the remainder *d* M of the arch should be carefully laid on the puddle, and a centering for the arch is to be laid on the same and firmly secured down; this precaution being necessary to prevent the semifluid puddle that is to be applied successively withoutside the arch, as it is carried up, from floating or burying up the centering along with the lower part of the arch. The work is thus to proceed until the part of the arch *d* M is completed, and inclosed completely in a case of good puddle, thoroughly and completely joined at one end into the puddle-ditch *a e f b*, and into the puddle that surrounds the well N M at the other. When the well-steining has been carried up to M, it will be necessary to increase the thickness of the puddle-wall round it, to three feet or more, taking care that the extra width is firmly bedded upon undisturbed and solid earth. The well is intended to be carried up in the same manner, surrounded by puddle, and by a conical embankment of earth O P Q R, to within two feet of the height of the bank H I, leaving a channel of several yards wide, and of considerable depth, I O P, between it and the bank or head D H I E. It will be necessary for the engineer to calculate and mark out the base of this conical embankment upon the ground, with allowance for ample slopes to prevent slipping or its washing down by the waves: it will also be proper, for ensuring stability to the work, to reduce the whole of the top of the work to one level as K L, as soon as can be, by successive layers of stuff thereon, and of puddle in the ditch *a e f b*, and round the well N M: and, if the bottom of the reservoir will require lining, owing to the porosity of the soil; it will be right, after levelling and treading the part *b* R perfectly, to cover the same with 3 or 4 courses or linings of puddle, joining the same perfectly with the puddle-ditch, and the puddle round the well, to which courses of puddle the bottom lining is afterwards to be carefully joined; and after this is properly set, the remainder of the bank L H I E. and of the cone O P Q R, may be proceeded with, as we have before mentioned, when treating of the rearing of canal banks with puddle-ditches in them. The bank or head being completed to H I, and the well N M, and conical embankment O P Q R, being also carried up to the proper height, the well should then be coped with a layer of the best hewn stones cramped together, and the top reduced to a perfect level; and for security, it will be right to pave the surface of the top P Q, and for some distance down the sides of the conical embankment, with paving stones pretty well jointed, and set their longest way into the soil, filling their joints with mould, and sowing grass-seeds therein, to prevent the waves from afterwards loosening the stones or wearing the bank; this conical bank is for enabling the water to fall into the well on all sides; if the well was made in a corner of the reservoir, much digging would be required, both for the arch or pipe to let out the water, and for the discharging arch D M.

We have been thus particular in describing the circular weir or well-fall above recommended, from having seen the beneficial effects of one, in the reservoir for Worsley mills

near the duke of *Bridgewater*'s canal; and the mischief that is sometimes done to the banks of a reservoir and the adjoining lands, by letting off the flood-waters by common weirs or tumbling bays at the corners of the reservoir, and suffering it to find or rather tear its own way down into the valley. Reservoirs constructed on the above principles would be secure almost from accident, however high the embankment, or sudden and copious the floods, if the well is but made sufficiently large, and deep of water at the bottom, to receive the shock of the descending column of water. If the floods are so considerable as to bring down timber and other large floating matters, it will be necessary to fix a strong grating or circle of bars round the top edge of the well bank PQ. It will sometimes happen, that a reservoir is over or near to the navigable tunnel of a canal, and might be let down into the same by a pipe and cock as at Ripley on the *Cromford*, and near Braunston on the *Grand Junction*. It will be proper, that the core or plug of the cock to a reservoir should be turned by an endless screw, or by toothed wheels, so that considerable power and nicety in the adjustment of the stream let out, by the turning of the cock, may be attained; and a register should be provided of the number of turns, and fractions of a turn, that is given to the winch or handle in any case. It will be proper to flanch on a small pipe to the large one, and connect the same with an inverted glass syphon filled with mercury, in the arch near the well, so that by turning a cock, the height of the mercury should indicate on a scale attached, what depth of water there is in the reservoir above, or how much it wants of being full at the time. A series of accurate experiments should be made, by gauging the stream of water at D, or at the first convenient place below it, which the cock discharges per hour or day, when the water is at different heights in the reservoir, and with different turns of the cock-geer; these should all be repeated, and sufficiently numerous, to enable the engineer by interpolation, to fill up and form a table, (that the committee ought carefully to preserve copies of) by which at any given height of mercury, the cock can readily be set to discharge any number of locks full of water that may be required per day. No great difficulty would attend the forming of a gauge-puddle, instead of, or by the side of the brass cock that should regulate itself, and discharge any regular and constant quantity of water that the reservoir could supply: see *Leybourn's Repository*, 8vo. question 81, p. 165. It will be right also for the engineer and committee, to have tables for readily shewing the quantity of water that every reservoir contains, at each foot or shorter portion of its depth, indicated by the mercury in the syphon, or by a graduated gauge-post fixed up in any part; for forming a table of this sort, where a complete survey had not been made or preserved at first, the time of a hard frost should be chosen, and a sufficient number of holes at equal distances, in a great number of parallel or equidistant lines, should be bored or cut through the ice sufficiently large to let down a plummet to sound the depth, and if this is done with care when the reservoir is full or nearly so, a most correct table of its content at different depths, can be thus obtained by calculation. Some of the considerable reservoirs that have been constructed for canals are, at Aldenham, Daventry, and Wilstone on the *Grand Junction*; Kilsyth on the *Forth and Clyde*; Branstone, and Denton on the *Grantham*; Ripley on the *Cromford*; Amsworth on the *Nottingham*; Littleborough on the *Rochdale*; Marsden on the *Huddersfield*; Oxendon on *Leicestershire and Northamptonshire Union*; in Rudyerd vale near Leek, for supplying the Caldon branch of the *Trent and Mersey* canal, which covers 160 acres, has its head 30 feet high, and the water in general very deep. St. Ferriol reservoir, constructed about the year 16[illegible], on the canal of *Languedoc* in the south of France, occupies a space of 595 acres, its banks are walled round with free stone, and its waters let out when wanted, by a large pipe and cock.

In *constructing Feeders* or channels to convey water to a canal from springs, brooks, or reservoirs above its level, the same care must be taken to examine the nature of the soil in every part, and to apply a lining of puddle, as have before been mentioned respecting the line of a canal, wherever porous stuff is to be cut through. Where there are a great number of undulations in the ground, through which a feeder is to be conducted, that would occasion it to be very crooked and much impede the cultivation of the land, it will be proper, in many instances, especially if the land be valuable, to cover over the feeder in a culvert or small arch of bricks, of 18 inches or 2 feet diameter, or larger if the supply shall at any time require the same: in very porous soils, these culverts, inclosed in puddle, will be the most effectual way of preserving and conducting small streams of water, and no land will thus be lost to cultivation. In some places, feeders will require considerable embankments and aqueducts, to cross valleys and streams of water, and preserve their level, or gradual and small fall; and in many of such cases it will be cheaper and better to use cast iron-pipes well jointed and flanched, and laid within the ground, down one side or bank of the vale to be passed, and up the other, securing each end carefully with a strong box full of holes, or a fine grating to keep extraneous matters out of the pipe. In the case of smaller feeders, particularly those temporary ones, which are required to supply water to puddle with, and to fill the bottom of the canal for the temporary use of dirt-boats while making it, as before mentioned, elm-pipes in short lengths, in which the most crooked arms of large trees will come into use, may be advantageously used in crossing hollow roads, or other sudden ravines, if the same be jointed by short hollow double cones of cast iron as recommended by Mr. *Hornblower*: see *Repertory*, vol. x. p. 25. It has often happened, where reservoirs are situate at some distance above a canal, and a brook-course led from the reservoir to the canal, that the water was left to take its ancient course on being let out of the reservoir; an expert engineer will, however, carefully examine all such feeders, for thus they ought to be considered, and fill up all deep holes, and lower the shallows in the brook-course, so as to reduce the channel nearly to an uniform width and depth; and very accurate gauges of the water ought to be made at different seasons of the year, of the quantity issuing out of the reservoir arch, and the quantity received into the canal; if these differ materially, intermediate and comparative gauges should be made of the stream, until the faulty or leaky ground is discovered, probably some stratum of sand or open-jointed rock; over which the brook-course or feeder ought to be carefully lined with puddle; and, if puddling-stuff be scarce, the soil very porous, and the brook-course very crooked, it may be the most effectual way, as well as the cheapest in the end, to pass such leaky ground by a small culvert, inclosed in puddle under ground, by the side of the brook-course, as straight as the course of the valley will admit. Except in situations, where mills in the vicinity of an intended canal are much in want of water, or their owners or others disposed to thwart the scheme, it has been usual to allow the company to search for, and divert to their use all springs of water, within certain limits on each side of their line; in the acts for the *Newcastle underline Junction*, the *Southampton and Salisbury*, and the upper part of the *Tamer Manure* canals, this limit is fixed at 1000 yards; in the *Aberdeen*, *Polbrook*,

Tamar Manure lower part, *Thames and Medway*, *Wilts and Berks*, and others, this is fixed at 2000 yards on each side of the line. In such cases, an accurate investigation and knowledge of the *Strata*, upon Mr. *Smith's* principles, will be of the most essential importance, in order to collect and retain springs that are above the summit level, or even in lower situations, where a local trade is to be provided for. It has been usual in some mining districts to require, that engines near an intended canal should lift their mine-water into such canal, or high enough to be conducted into it by a feeder, as on the *Birmingham and Fazeley* canal. It will be worth considering, on a summit, where water is scarce, whether a tunnel may not be more eligible than deep-cutting, on account of large springs which would be intersected by the lower level of the former, when the deep-cutting must perhaps be in porous stuff, or perhaps in dry open rock. As the summit pounds or levels of most canals are in deep cutting, through a considerable portion of their lengths, it is often attended with but little additional expence, except in the case of tunnels, to make such summits pounds one or two feet deeper in water than usual, as on the *Derby*, *Cromford*, *Manchester Ashton and Oldham*, *Oxford*, and other canals, in order that such additional depth, being filled in winter-time or wet seasons, may act as a reservoir for drier ones; but it has not always been considered, that such deeper pounds, when filled 18 inches or 2 feet fuller than is necessary, occasion the necessity of letting off twice that extra depth of water, over the area of a lock, each time that a vessel passes the summit; by which, such reserve of water is in a great measure dissipated before the dry season for which it was intended arrives. We should recommend, either the use of reservoirs, so much above the summit level of the canal, that they could be emptied into the same, when the continuance of dry weather required it; or, if such deeper summit pounds be made, on account of their considerable length for holding water, that a lock capable of penning 18 inches or 2 feet, and of shutting very tight, should in such case be built, near each end of the summit, to be used as long as the summit water is higher than usual, but which might at other times be left open, when the water was level on each side of them. Before we quit the subject of supplying a canal with water, we beg to mention, that it may be worth the while of the engineer, where water is to be pumped up to supply the lockage, as we have before mentioned, to design and calculate the expence of wind-machines, capable of doing the required work, and of the probable expence of their repair; and to compare the same, with the cost of erection, expence in fuel, attendance and repairs, of well constructed steam-engines to do the same work.

On the *erection of Aqueducts* for conveying a canal over any very deep and wide valley, or over a large or navigable river, we beg to mention, that a most secure foundation must be sought for, by sinking, or obtained by piling, for the piers of an aqueduct-bridge, and that the arches ought, in every case, to be arches of *equilibrium*, because the least settling in brick or stone bridges, by letting through the water, may prove of the most fatal consequence. That the plan of an aqueduct-bridge should be curving inwards, that is, the ends should be wider than the middle, the walls should also not be upright, but buttering or diminishing upwards with-outside, to give greater strength and stability to the whole; the materials, if of stone or brick, and the cement, should be of the very best quality, and the work executed in the summer season only. In *Plate II. Canals*, *figs.* 19, 20, and 21, we have given a plan, section, and elevation of an aqueduct-bridge, proper for crossing a considerable river, where, in *fig.* 19, A is the river, B the canal, C the towing-path, and D D the wing-walls, for keeping up the embankments at each end of the bridge: in *fig.* 20, C is the towing path, and *a a* a lining of puddle to secure the canal B from leaking. Care should be taken that all the joints of brick or stone are worked as close as possible in an aqueduct-bridge, and thoroughly filled with cement; the slopes within side, and the bottom for the canal, should be made rough, that the puddle may the better adhere to them, and that the puddle may not slip, owing to the steepness of the sides, which must be more so than in other parts of the canal, to avoid unnecessary expence of masonry or brick-work in the width of the bridge. The lining as above is, however, liable to be soon cut away by the barges. Since the year 1795, a new kind of aqueducts has been introduced into this country, composed partly of cast-iron, which promises the greatest advantages, except, perhaps, where free-stone of an excellent and durable quality is found upon or very near to the spot, or where the same is very distant from any iron mines, or existing navigations that connect with such. In the year 1797, Mr. *Thomas Telford*, the engineer, wrote an account of the inland navigation of the county of Salop, which has since been printed in J. Plymley's Report to the Board of Agriculture, on the Agriculture of Shropshire, and we beg to extract therefrom what he says on this subject when speaking of the *Shrewsbury* canal, p. 299, as follows: "This canal passes over the valley of Tern, at Long, for a distance of 62 yards, upon an aqueduct made all of cast iron, excepting only the nuts and screws, which are of wrought iron; and I believe this to be the first aqueduct for the purposes of a navigable canal which has ever been composed with this metal. It has completely answered the intention, although it was foretold by some, that the effects of the different degrees of heat and cold would be such as to cause expansion and contraction of the metal, which not being equal to extend or draw back the whole mass of the aqueduct, would operate upon the separate plates of iron so as to tear off the flanches which connect the plates lengthwise, and break the joints. Others said, that the expansion of freezing water would burst the sides, and so break off the flanches which connect the sides with the bottom plates: but after the trial of a summer heat, and the very severe frost of the winter of 1796, no visible alteration has taken place, and no water passes through any of the side or bottom joints. After the frost had continued very severe for three or four days, and the water had not been drawn off (although there are means of doing so), but it had stood in the aqueduct above the height of two feet six inches, the ice had then frozen to the thickness of an inch and a half, but instead of having forced out the sides, it was melted away from them, and quite loose upon the surface of the water. The idea of having this aqueduct made of cast iron was first suggested and recommended by *Thomas Eyton* esq. then chairman of the committee: after due consideration, it was approved by the committee, and the principles of construction, and the manner in which it should be executed were referred to Mr. *William Reynolds*, and the writer of this article, (Mr. *Telford*) who, after several consultations, and forming and considering various plans, at last determined upon that which is represented by the annexed engraving, (*Plate III. Canals*, *fig.* 22.)

"The castings for the aqueduct were done at Ketley, and were removed to Long, a distance of five miles, partly by land and partly by water-carriage. This aqueduct was proposed in consequence of the great floods which happened in the beginning of the year 1795, and it was fixed up complete

in March 1796." Mr. *Robert Fulton*, an American engineer, who happened to be in this country at the time, seems to have availed himself of what was going on at Long aqueduct as above, and of the machinery of various kinds, in use upon the *Ketley* and *Shropshire* canals, and to have prepared drawings and models of a variety of such machinery, with many improvements of his own, and submitted the same to the examination of a committee of the Board of Agriculture, in March 1796. These have since been published in a handsome quarto volume, entitled, *A Treatise on the Improvement of Canal Navigation, by R. Fulton*, from which, p. 114, we beg to extract what he says on constructing aqueducts of cast-iron for a narrow canal as follows: "The butments and piers being raised, it will only be necessary to extend two pieces of timber across the span; each to be braced back to the piers, and covered with plank to form a stage or scaffolding which will answer every purpose of centres necessary to works of stone. The iron-work, as in the section (*Plate* III. *Canals, fig.* 23 *and* 24.) may all be cast in open sand, and of the following dimensions: supposing the span 100 feet and the spring one-sixth of the span. First, three segments of a circle, each in three pieces, about 36 feet long, eight inches by four diameter, to be united, as at A. Second, three straight bars, to extend from one pier to the other, to be of the above diameters, may also be cast in three pieces, which bars are to extend along the top of the segments to the piers, and form a line parallel to the horizon; the bars and segments to be united by perpendicular stirrups like B, ten or fifteen feet distant from each other. The mortice in the lower end of the stirrup being thirteen inches long, will be sufficient to secure the segment, and leave room for a hole two inches square, through which a cross brace, C, is to pass, and fasten the segments at proper distances; the brace to have a mortice cast on each side of the stirrup, in order to tighten the work by wedges. On the top of the stirrup, the square hole to receive the cross brace may be beneath the mortices, as in the figure; by which means the whole may be combined, and form an iron stage to support the troughs. The trough plates should be at least one inch thick, the side plates six feet broad, and as great a length as can conveniently be cast; which may be performed twelve feet, and perhaps more in length: the flange to be outside on these plates. The bottom plates may be six feet wide, thirteen feet long, seven feet plate, and four arms projecting, each three feet long, in order to support the horse-path and braces, as exhibited at D. Two of these plates laid across the stage, and screwed together, with a flange under, will compose a length equal to one of the side plates, which may either meet or break joint as is thought proper. The whole may, in this manner, be screwed together, on packing of wool and tar, and have the seams pitched like those of a ship. On the plates composing one side of the trough, small brackets, about three feet from the top, must be cast, as at E, in order to support the horse-path; perpendicular rails, eight feet long, being raised from the arms of the bottom plates, will support the outside of the horse-path, also the iron railing, as in the section. By this mode, two patterns will answer for the whole of the trough-plates, and but few will be required for the springs, rails, and spurs; while the saving in time and expence will be considerable; particularly where it is necessary to bring the stone by long land carriage; for the arches being dispensed with, and the piers not more than one third of the dimensions necessary to an aqueduct of stone, will most materially reduce the quantity of masonry." "In aqueducts of stone, one of the great difficulties is to line and puddle so tight as to prevent the water penetrating into and injuring the masonry; but in one of iron, should a leak take place it will instantly appear; and on shutting the stop-gates at each end, and discharging the water, it may be stopped in a few hours, if not minutes: this circumstance in aqueducts is, perhaps, one of the greatest preservatives; they are consequently less liable to injury, and only subject to the corroding tooth of time."

Since the above period, a most stupendous work of this kind has been undertaken by Mr. *Jessop*, on the *Ellesmere* canal, and is now nearly or quite completed, for crossing the Dee river at Pontcysyltee, about 20 miles S.W. of Chester; where nineteen massive conical pillars of stone, at fifty-two feet from each other, the middlemost of which is no less than 126 feet in height, support between the top of every pair, a number of elliptical cast-iron ribs, which by means of uprights and horizontal bars, support a cast-iron aqueduct about 329 yards long, 20 feet wide, and six in depth, composed of massive sheets of cast-iron, cemented and riveted together, having on its south side an iron platform and railing for the towing-path. In May 1796 Mr. *James Jordan* took out a patent for suspending aqueducts from ribs of cast-iron above them, in the same manner as his suspended iron bridges. See *Repertory*, vol. vi. p. 230. Among the most considerable aqueducts of stone or brick are those at Lancaster on the *Lancaster* canal, for a description of which see our article BRIDGE. At Kirkintolluch and at Kelvin on the *Forth and Clyde*, Chirk on the *Ellesmere*, Marple on the *Manchester Ashton and Oldham*, Monk-bridge on the *Trent and Mersey*, Whaley-bridge on the *Peak Forest*, Avoncliff and Dundas on the *Kennet and Avon*, &c. while at Burton on *Bridgewater*'s, a navigable river is passed, and near Wigan on the *Leeds and Liverpool*, another canal (the *Lancaster*) is passed upon aqueducts. It was thought a bold and visionary scheme by many, which Mr. *James Brindley* proposed, of crossing the *Mersey* river at Runcorn Gap, by an aqueduct bridge, but no doubt he could have accomplished it.

The *making of Embankments* appears to have been long practised in China, where we read of parts of their canals of 200 feet wide, that are embanked 20 feet high, for great lengths together; the rivers through the fens of Cambridge and Lincolnshire in this country, have also been long confined thus, by artificial banks. Most of the aqueducts of which we have been speaking above, have less or greater lengths of solid mounds or embankments for forming the canal upon, to the proper height, and for joining them to the aqueduct bridges; all the observations and remarks which we have made, respecting the setting out and ascertaining the dimensions of the head of a reservoir, will apply to embankments; except that a prism whose base is the figure G H I L M N O I, *Plate* IV. *of Canals, fig.* 25, and length A B, *fig.* 16. *Plate* I. is to be deducted from the triangular embankment D G F, first to be calculated, instead of the triangular prism G H I. The angle of the slopes ought to be determined by the result of similar inquiries, and the same precautions used to prevent slips, in soils that are so disposed, as were mentioned respecting reservoir heads; it will generally be a safer way to carry up a puddle-ditch in each bank of the canal, as *a e, b f, fig.* 25, than to trust only to lining of the canal L M N O. In every considerable embankment there will be required one or more arches to convey a brook or river under the canal, and, perhaps, others for roads to pass through; such arches should always have an inverted arch turned below them, deep enough for the bottom of the brook, and below the roads, and the arch itself should be one of *equilibration*. To avoid making a very large arch for a brook or small river, it is usual to make a road or communication arch near it, with

its bottom well paved, and no higher than the surface of the meadows, which will serve to vent the sudden flood in rainy seasons.

Great care should be taken to slope off and finish the ends of arches under an embankment, agreeable to the slopes or sides of the banks thereof; by which the banks are prevented from mouldering down into the brook or road-way, and awkward projections in the slopes of the banks are avoided: at the entrance or upper side of a water-arch, or of road-arches that will occasionally become such, return or wing-walls of brick-work or stone should be made, for some distance along the bottom of the slope of the embankment, and the sharp corners of the entrance of the arch should be a little rounded off, to prevent the rapidity of sudden floods from wearing or injuring the bank. It is to be observed, in conducting a canal along the side of a steep and high hill, as *Plate* I. *fig.* 3, that after a certain degree of steepness of the ground A′ P′, it will not be possible to cut the canal, upon the principle that the excavation E F G I K P shall just form the bank A B C E, but such banks will often require stuff to be provided from other places, and such are indeed cases of embankment: and here it may be proper to advise, that new banks, as A B C E, ought not to be placed on very steep ground, as A E, without considerable care in first forming it into levels like steps, to prevent the slipping of the new part, as happened near Bradford on the *Kennet and Avon* canal, after all the care that was taken, and great lengths of the canal banks slid down into the *Avon* river below, the making of which good again cost, we were told, near 1000l. Among the considerable embankments that have been made for canals, are those at Bollin and Stretford on *Bridgewater*'s, and Wolverton, Weedon, and Bugbrook on the *Grand Junction*, &c. but the greatest extent of high embankment known, is that in the valley of the Boyne, in the *Grand* canal of Ireland; and the highest bank in the world is also to be found on the same canal in the valley of the River Rye; it is above 90 feet high. We are told, that Mr. *James Brindley* used a kind of caisson of planks, in forming his great embankments, in which dirt boats were used, to bring stuff from the higher ground, that had been cut through.

We have next to speak of *Safety-gates*, *Stop-gates*, and *Stop-planks*, which are different contrivances for stopping the water of a canal in case the banks are failing in any part, or that any part wants emptying to repair the works. Advantage is generally taken of the walls under the bridges, for constructing these contrivances, where the same happen in the proper places; otherwise the canal must be contracted by upright walls, the same as is done at the bridges on purpose for them. For explaining the nature of safety-gates, we must have recourse to *fig.* 26, where A B is supposed to represent the top of the wall, or height of the towing-path under a bridge, C D the surface of the water, and Q S the bottom of the canal; E F G H is a pier of hewn stones, or a piece of sound oak timber let into the wall, its face being flush therewith; I E G and H F K are recesses about two inches deep in the wall; similar provision is made in the opposite wall, for receiving doors or gates L M and N O across the canal, turning on centres or hollow-quoins at M and N: each gate is so balanced by a counter weight, that they rest always in the position represented: and they are intended to operate thus, suppose, owing to the sudden breaking of a bank, the water in the canal should acquire a current from Q towards S, the stream would pass under the gate at P L, to facilitate which, the corner of the floor at P is sloped off; the gate would be turned up into the position M E, and the canal would be thereby closed up. The like would happen by the other gate N O, in case of a current the contrary way. Safety-gates should be placed at proper distances on every long level or pond of water, especially if the same is much embanked; both to prevent the loss of so much water, in case of a bank breaking, and the mischief that the same would do to the lands, mills, &c. below the breach. We read of a new bank breaking on the *Warwick and Birmingham* canal, and destroying a gentleman's park-walls; and in the year 1783 so great a breach suddenly happened on *Bridgewater*'s canal, near London bridge on the Chester road, that three barges were carried through the same a great way out into the fields. A single safety-gate ought to be placed at the end of every long embankment, to stop the water in case of a breach happening in its banks. *Stop gates* are similar in their construction to the safety-gates above described, except that the gate lies flat on the bottom of the canal instead of being balanced, and has a chain by which it can be hauled up, whenever occasion may require the canal to be stopped. *Stop-planks* are a simple, though not so expeditious a provision for stopping a canal as the last; a groove is provided in the two opposite walls under a bridge, or in a narrow and walled place, and a sufficient number of well jointed planks are provided, to be dropped into the groove whenever the water is required to be stopped, and hence these are often called drop-planks. In very large works like the *London docks*, a barge or vessel is built in the place, whose head and stern posts exactly fit into a groove as above, and the vessel can be floated into and out of its place, or sunk therein as occasion may require. The engineer will also have to make provision, while the canal is digging, for *stop-bars* at the several intended toll-houses, or other places where it may be necessary to stop barges in the night, or in case of any dispute about their lading: these bars are composed of a large baulk of fir timber floating on the water; and a small arch capable of containing such a floating beam of the proper length is provided under the bank, so that when the trade on the canal is required to be stopped, the toll-clerk has only to draw out the beam by means of a cord attached to it, until its end enters a recess in the opposite wall, and then to lock the beam fast.

We shall next describe the *Waste-gates*, *Trunks*, *Tumbling-bays*, or *Weirs*, that must be provided, for letting off the superfluous water of a canal in wet times, for keeping the water to one certain height, or drawing it off in case any repairs may be wanting. *Waste gates* are sluices of the common construction in the side of a canal, where any considerable quantity of water is required to be let out, and are to be drawn up, either by a rack and pinion, a chain and roller, or a number of holes for a crow-bar, as circumstances may render most eligible: where lesser quantities of water are to be let out, or for emptying certain lengths of the canal between the stop-gates or planks, when occasion may require; *trunks* formed of oak or elm planks, well jointed, should be laid into the bank, at the bottom of the canal, and carefully inclosed in puddle, with a valve or shuttle that will shut very tight, and can be readily drawn when the water is required to be let off: we beg to recommend, wherever wooden trunks are used for any such purpose, that they should be sunk so low, or the mouth where they discharge should be made up, so that the trunk may always remain quite full of water, and the air be at all times excluded; in which situation wood will last much longer than if wet and dry alternately.

In the choice of situations for *weirs*, to discharge the surplus water of a canal, care must be taken not to let off any considerable quantity at any time, but into a brook-course or bottom of a vale, that is crossed or proceeds up to the canal, and has ditches through which the water can escape,

without tearing or doing injury to the land adjoining. The most frequent *tumbling-bays* or *weirs* to discharge water from canals are composed of strong walls of brick or masonry, as *qc*, *Plate* IV, *Canals*, *fig*. 27, whose top *q* is coped with hewn and well jointed stone, or with a stout sill of oak, the top of the same being just level with the top-water line *q* D H, or about one foot lower than the top-bank D C I K, A *c* is a paving of large stones for the water to fall on, and escape at A, and A B *c* are wing-walls at the ends of the weir, to keep up the bank and confine the water. These weirs are generally on the towing-path side, on which a low plank bridge, as C *l*, is supported over it, called a weir-bridge. When these weirs are wanted of considerable length, the wall *qc* ought not to be straight but on a circular plan, curving inwards in the middle, by which it will be better able to support the lateral pressure of the bank behind it; a puddle ditch should be carried up immediately behind the wall, allowing the courses of puddle to set thoroughly, before others are applied, that the great pressure of the semifluid puddle may not overset or disturb the wall; and the paving AC should be of large and well jointed stones, and if set upon a course of puddle it would be a further security against their washing up, which too often happens. We have seldom seen any considerable weirs or tumbling-bays of the above construction, but where it would have been better to have followed the example of Mr. *James Brindley*, on *Bridgewater*'s canal, and have made a *circular-weir*, or well-fall, on the upper side of the canal; we have spoken of these when treating of the general improvement of a valley, as also in the making of reservoirs, but it may be proper here to refer to a section of such a well-fall in *fig*. 28, where A′ P′ is supposed to be the section of a vale crossing the canal C F G I; A M is an arch of brick-work, secured on its upper side at least, with a covering of puddle, and M N is a well, whose steining or lining of brick or stone is groined into the arch at M, having a well paved floor, three or four feet below M, according to the height N M that the water is to fall, and a coping of hewn stone, or a large curb of sound oak at its top. I O P Q R P′ is intended to represent the section of a side pond or wider place in the canal, from which the water may drop quietly into the well at N from all sides, and run off at A.

For letting a proper quantity of the surplus water of a canal forwards into the ponds below, a small weir is generally constructed in the walls at the head of each lock, which lets the water down into the paddle-holes, or crooked arches that convey the water for filling the locks, and hence such are called *paddle-weirs* or lock-weirs. The upper gates or doors of the locks are often boarded no higher than the top-water line, and therefore act as weirs for discharging surplus water into the lock; and gates of this sort are called *flood-gates*.

On the *construction of Culverts*, or drains under a canal for conveying away water from the upper to the lower side of the canal, it remains for us to say, that they should be carefully apportioned in size to the stream that is to pass through them in floods, and should be constructed of sound brick or stone work, and inclosed, or at least well covered on their upper side with puddle. Many engineers have used wooden trunks for this purpose, but except wood be in great plenty, and of the best quality, and good bricks or stone very difficult to be procured, it is not advisable to use perishable materials in such situations. If the ground be moory or bad, and a culvert must lie pretty near to the bottom of the canal, and have but a slight covering, it may be proper, in some situations, to use cast-iron cylinders flanched together, as was done under or near the *Staffordshire and Worcester* canal; and such may be made cheaper and easier of carriage, by being in two or three segments longitudinally, to be flanched together before they are laid down; and in such situations, perhaps leaden rivets might be cheaper and be more durable than wrought iron ones, or nuts and screws. If bricks are to be used in culverts, over soft and moory ground, or quick-sands, a cradle composed of ribs of wood and boards or rails, such as are used for centering, should be prepared, suitable to the outer curve of the intended culvert, and such a cradle should be carefully embedded, in the proper place to receive the bricks of the lower segments of the culvert: for want of such precaution many a culvert has sunk partially, perhaps owing to the springs excavating the sand or filth from below, and has been broken, to the great injury of the canal. Culverts are of so much importance, that too much care can hardly be taken to make them solid and secure, and to cover them effectually with puddle: another hint we would here give, respecting the choice of places for the culverts; they should never, if possible to avoid it, be made exactly in an old brook-course, ditch, or slough, but in the nearest sound ground; and where often they can be got down to the proper depth, without any trouble from water, or at least the same can be easily pumped out; and the stream need not be admitted to the work, until the old brook or slough is required to be filled up. In this way it often will happen, that culverts may remain during the winter following their construction, completely excluded from the frost, and therefore may be done later in the year, by filling in the stuff upon them and at their ends, and the mortar be completely set before the new channel at the ends for conducting the water through them need to be cut. And we beg to remark, that by an attention to this circumstance in making new arches under roads, and keeping the bottom of the arch much lower than is generally done, or indeed practicable in the old channel or slough, half or two-thirds of the whole expence will generally be saved; for a deep and new channel being cut to the new arch; with scouring out the brook-course for some distance below, old ford-places, if the descent to them be easy and convenient, will not require immediately to be filled up or altered; but during any extraordinary flood, the same, if composed of gravel and hard stuff, may act the part of a weir for a short time, in carrying off the water, without injury to the road or material inconvenience to the passengers. It will sometimes happen, that a small stream of water is required to pass under the canal, in places where it is not embanked; in such cases a crooked or *broken-backed culvert* is to be made, as *m o o n*, *fig*. 29, for passing the water from *m* to *n* under the canal C F G I; this will require puddling as before described, and a strong box full of holes, or grating, should be fixed over each of its ends, as well as pits or holes be made at the upper end, deeper than the mouth of the culvert, to receive and detain the sand and gravel which the stream may bring down in hasty rains, otherwise these, or the stones that mischievous boys might throw into it, would in time choak it up between *o* and *o*.

The *construction of Tunnels*, or subterraneous arches, for drawing off or conveying of water, has been known from the earliest periods, as appears by the celebrated works of this kind between lake Copais in Bœotia and the sea; between the lakes formed by the inundations of the Nile in Egypt and the Mediterranean; as also by the courses of the Roman aqueducts, many of which were tunnelled through hills of great extent. In the mining districts of this country, we have long had levels or audits of considerable extent to mines; in the neighbourhood of Matlock in Derbyshire, the *Helcarr Sough* has been cut through the solid rock for nearly four

miles in length, for the purpose of draining the several lead mines in the vicinity; *Wirksworth Moor Sough*, of near three miles long, and *Cromford Sough*, of two miles in length, with many others of less note, are also to be found at great depths in that neighbourhood. The first *tunnel* that we read of, as constructed for the purpose of navigation, was by M. *Riquet*, near Bezieres on the *Languedoc* canal, in France; and the first in this country, was the entrance made by *James Brindley* to the duke of *Bridgewater*'s coal-mines at Worsley near Manchester; while the first of our tunnels undertaken for the purposes of general trade, or as a thoroughfare, was by the same engineer at Harecastle on the *Trent and Mersey* canal. It is very essential to the convenience as well as the beauty of a tunnel, that the arch thereof should be quite straight, and exactly level; considerable care will therefore be necessary in obtaining an exact section, by levelling, of the hill that is to be perforated, when a line in the exact vertical plane of the tunnel is fixed and staked out over the hill; in doing which, it will be right to choose the narrowest place that the hill presents at the proposed level, and where also the hill rises rather boldly from such level; otherwise an expensive and troublesome length of deep-cutting would be necessary, or of the tunnel that must be dug out from above and then covered up again, before a sufficient depth of stuff over head would be come at, to admit of working under ground; it will also be of consequence, when determining the exact line for a tunnel, to avoid having the deep-cutting and entrances in alluvial or disturbed and slippery soils, but, if possible, to enter at once upon the solid and undisturbed *strata* of which the hill is composed.

It will but very rarely happen, and that only on short tunnels, made for the purpose of preserving the level of a canal, that the workings will not be in soil more or less full of springs of water; therefore one of the first operations, after the line and level of a tunnel is finally determined on, is to search by levelling for a place in the nearest vale or brook that is some feet below the proposed level of the bottom of the tunnel; this must be more or less, according as the intended tunnel is of greater or less length; and from this point a large ditch must be opened, with a very small rise towards the end of the tunnel, as far as is practicable, and then a *heading* or sough must be begun, just large enough for men who are used to such business to work in, and to line it securely with bricks as they proceed, but leaving proper openings in the joints for the springs to collect freely from all sides into their heading. Some persons have supported their headings with boards and props of wood, instead of arching them; but which practice we cannot recommend: all such works ought to be durably constructed, or should any accident or circumstances, as the want of money, &c. delay the completion of the work for some years, all this tedious and expensive work will perhaps require doing again; it ought also to be considered, that after some years or ages have elapsed, the tunnel may want repairs or alterations, and that the same headings may be again opened and used, to lay it dry in a short time, if durably constructed; which may be of the most material consequence in lessening the period of interruption to the trade by such repairs or alterations. It will be necessary to begin a heading as above-mentioned on each side of the hill, and work them up towards each end of the tunnel, along the line of which it is to proceed from each end, rising gently as it advances towards the middle point, that the water may run freely off; the headings should be a few feet below the bottom of the working, that will be necessary for the inverted arch of the tunnel, and a few yards off on the side of it; and cross headings or soughs must, at stated distances, be run under the line of the tunnel, into which, openings can afterwards be made to let off the water which collects in each separate working. If the soil be rather stiff, and the quantity of water in it not very considerable, one heading may suffice; but where porous stuff, with great quantities of water are intersected, it will be necessary to branch off an additional heading, to proceed along the other side of the line, the more effectually to draw off the water; by which, perhaps, if the headings are done a sufficient length of time before the tunneling is begun, a quick-sand, or similar running of the stuff, may in several places be prevented. If in driving the headings, any fissures or cavities filled with sand or loose matters, are intersected, and are found to bring a considerable quantity of water from one side of the line, it may be right to drive a cross heading for some distance into such porous stuff, for intercepting the water before it reaches the intended workings of the tunnel.

The next operation will be to set out a line very truly parallel to the line of the intended tunnel, and to mark thereon, at equal distances, about 150 yards apart, or oftener if great expedition in completing the tunnel is required, the place of the several tunnel pits, that are to be sunk for drawing up the stuff excavated from the tunnel, and letting down the centres, bricks, and other things wanted in the work; it will be well to contrive the line of the headings and tunnel-pits, so that they may coincide; and in great lengths of heading shafts or tunnel-pits may be sunk at intervals, to give air to the headings, and through which the stuff excavated therefrom may more readily be drawn up; and it may be advisable, in some instances, to set out a line on each side of the tunnel, for the tunnel-pits to be some on one side and some on the other of the tunnel, and that both may in places intersect the headings. If bricks or stones are not at hand when the tunnel-pits are begun, and wood is plenty, the shafts or tunnel-pits may be made square, and have their sides supported by boards and struts of wood; otherwise they should be made round, and lined or steined like a well as soon as they are done; if the soil should prove loose and full of water, it will be necessary to stein the shaft as soon as such soil is reached, and to work afterwards from underneath the curb, and let the steining sink, as is done in well sinking. Some tunnel pits have been made over the line of the tunnel, but such do not admit of being steined with safety, on account of the weight thereof, which would damage the crown of the tunnel, where they were groined into each other; and such of them as are left afterwards for air shafts, if the soil is wet, will let an unpleasant dripping of water down upon the goods or passengers in passing through the tunnel, as we once experienced in passing through Braunston tunnel on the *Grand Junction* canal. A common roll and winch will be sufficient for drawing up the stuff and water, and letting down bricks to stein with, unless the quantity of water is considerable; but it will be proper to erect a horse gin, or turn beam, such as are used at the shafts of coal-pits, for the cheaper and more expeditious drawing up the stuff and letting down of materials, when the workings have commenced. We have before recommended a line to be staked out exactly parallel to the line of the tunnel for the centres of the several tunnel-pits, and care should be taken that no gin, or other obstruction, be erected in this line, so that a fine line or string can at any time be stretched across the top of any of the tunnel-pits, and be adjusted without fear of mistake in the exact range of this line, or parallel to the intended tunnel. When a tunnel-pit is completed and steined, and a communication formed with the heading to keep the same clear of water; two points must be fixed in the steining near its bottom, by letting fall or suspending plumb-lines, at the time that there is no wind to disturb their verticality, and adjusting

another fine line between the two points on the fteining below, fo as to be exactly under and parallel to the line above and confequently fo to the intended tunnel. The engineer fhould carefully repeat his levels and transfer the level of the bottom of the intended tunnel, or the furface of the water of the canal therein, and mark the fame carefully in the fteining of each tunnel-pit: and thus the workmen who are to undertake the work will be furnifhed with the direction, level, and diftance of the tunnel they are to form under ground.

The work commences, by excavating a paffage from the tunnel-pit into the line of the intended tunnel, and fupporting the fame properly with timber, or walls and an arch, as a paffage into the work. A piece of the intended tunnel, a yard or more in length, according as the foil is found to ftand, is then excavated, in the proper form, place, and level, afcertained from time to time by ftretching a fine line between the marks, on the fteining before-mentioned, and meafuring therefrom, and ufing a common plummet-level for transferring the level from the level-mark on the fteining before-mentioned; great numbers of ribs for centerings fhould be prepared in different fegments, and in readinefs to put together with nuts and fcrews, leaving as much room in the middle or centre as can conveniently be done, for the men to work and pafs through after the fame are put up; the parts of two of thefe ribs are then to be let down the tunnel-pit, and to be put together and fixed up in their proper place and diftance afunder in the tunnel; fhort lengths of boards or laths are to be prepared and fixed on their outfides, as the turning of the arch proceeds; which, as well as every other part of this very difficult work, requires the utmoft care and experience to make it found and fubftantial; when this firft yard or lefs in length of the tunnel is turned and fecurely keyed up, the fame is fecured by ramming in clay, or proper ftuff, fo as to fill every cavity above or withoutfide the brick-work. The workmen then begin at each end of the piece that is turned, one party working one way along the line of the tunnel, and another the contrary way, until another yard or other length of the tunnel is excavated, when other ribs are put up and fixed together, boarded, and the brick-work is turned round or behind, the fame as before; the utmoft care being taken to joint thefe courfes evenly and fecurely into the former ones: the vacant fpace is then rammed up with earth, and a new excavation proceeded with at each end as before. The engineer ought frequently to renew his level-marks from fixed and good bench-marks on the ground, and to examine and adjuft the ranging line, and alfo himfelf moft carefully infpect each working of the tunnel, and examine, by ftretching a fine line along its centre, and meafuring and levelling to his ranging line in the tunnel-pit, to fee that every part of the work is proceeding exactly in the fame line, and fo that when in procefs of time each adjacent working fhall be joined, and the tunnel be completed, the whole may form one exact and truly ftraight arch. If the ground proves loofe and bad for ftanding, it will be proper to continue the work, by different fets of men, without any intermiffion; and care fhould be taken that the work never is left, even for a night, without templets, or fhort pieces of plank, being put up to cover the roof, that is neceffarily left open to admit the men's heads and arms, while they are turning and backing up their laft length of work at the crown; and thefe templets fhould be fecurely fhored up by fpars or ftruts, to prevent the earth from fettling or falling in, which has actually happened in fome tunnels, owing to the neglect of this fimple and neceffary operation, fo that a confiderable length of the tunnel required to be dug out from the furface of the ground to repair the breach. When the tunnel and ends are completed, ditches are to be dug out, acrofs the headings, near the entrances of the tunnel, and a fubftantial puddle-ditch carried up, to effectually dam them up, and force the water that afterwards collects in them to rife up into the tunnel, through crofs-headings to be left for that purpofe.

The tunnel at Blifworth, on the *Grand Junction* canal being the lateft that has been completed (Feb. 1805.) we have afcertained the following particulars relating to it, in order to give fome idea of the prefent ftate and expences of tunnel making. The internal width of this tunnel is $16\frac{1}{2}$ feet, the depth below the water-line to the inverted arch 7 feet, and the fofit or crown of the arch is 11 feet above the fame line. The fide-walls are the fegments of a circle of 20 feet radius, the top arch of one of 8 feet radius. The fide and top walls are 17 inches, or two bricks thick, and the bottom or inverted arch 13 inches, or $1\frac{1}{2}$ brick thick; every fifth courfe of the top arch, and every eleventh of the fide walls, is compofed of two heading bricks, or wedge-like, one inch thick on the infide and three at the back; alfo, every fifth and eleventh courfe as above (but between the courfes of heading bricks) are compofed of bricks laid obliquely acrofs the others, the front and back corners being cut off for that purpofe in the making, for more effectually breaking the joints, of work obliged to be done in fuch fhort lengths. The mortar that was ufed, was compofed of one bufhel of Southam lime (*blue lias*) and three of good fand. Six inches under the water line, on each fide of the tunnel, flide-rails of fir, 5 inches fquare, to keep the barges off the walls, are fixed by pieces of oak let into the wall below them; which rails project 9 inches from the wall, and have at every 9 feet, a chock of wood upon the rail, for the bargemen to fet their pole againft for fhoving their barges along. And we were told that this tunnel was contracted for, at 15*l*. 13*s*. per yard run; the foil principally a hard blue clay, with two or three thin rocks in it. Sufficient headings had been executed feveral years before at the company's expence. The fame contractors were paid $10\frac{1}{2}$ d. per cubic yard for excavating the deep cutting at one end of this tunnel, and 11 d. per cubic yard for the other. The expence of driving the above headings were, we underftood, from 36*s*. to 42*s*. 6*d*. per yard run. Nineteen tunnel-pits, fome of them 60 feet deep, were funk for the ufe of the above tunnel, which coft about 30*s*. per yard in depth including fteining. In our inquiries refpecting Braunfton tunnel, on the fame canal, we were told, that 320 yards of the fame was drove in quick-fands, and that it coft 4800*l*. extra on that account. The Foulridge tunnel on the *Leeds and Liverpool* canal, of 1630 yards long, proved to be in fuch very loofe and bad ground, that the whole of it, but about 700 yards, was obliged to be dug out from above; in fome parts 30 yards wide at top, and near 20 deep, and immenfe works of timber were neceffary to fupport and keep the banks apart, while the tunnel was turned, and the foil filled in again. Some part of this work, done about the year 1794, coft 24*l*. or more per yard run.

After a good length of the tunnel has been completed and well backed up, and been allowed fome days or weeks for the earth to have fettled regularly upon the brick-work, the centering may be removed, by loofening the fcrews and taking it to pieces, to be again put up and ufed further on in the fame working. In tunnels upon high levels in porous foils, and in others fometimes near their ends, or in croffing any dry and porous ftratum, it may be neceffary to excavate the bottom a foot or 18 inches deeper than ufual, and to fill the fame up again with well wrought and ftiffifh puddle, and to turn the inverted arch, and as much of the fides as are below the water-level, upon the fame, when fet. Mr. *William Chapman*, page 52 to 54 of his *Obfervations*, &c. before

quoted, has given feveral directions for fetting out tunnels, where coal-ftrata are intended to be interfected and worked thereby, as at Worfley on *Bridgewater's*, and Harecaftle on the *Trent and Merfey* canals. It will be a matter of fome importance, for the engineer to attend to the removing of the top-foil from a fufficient fpace near each tunnel-pit, and to caufe the fame to be evenly covered, or the holes therein filled up, with the ftuff that is drawn up and wheeled away from the tunnel-pits; and as faft as the different parts of the tunnel are completed, referving ftuff enough to fill up fuch tunnel-pits as are not to remain for air-fhafts, to caufe the top-foil to be returned upon fuch places, to avoid a heavy expence for fpoil banks, befides putting the farmers and neighbourhood out of temper by feeing the apparent wafte and devaftation that fuch works make, when carelefsly or negligently performed. The want of a towing path through a tunnel muft be very apparent, to all fuch as have feen the tedious and barbarous procefs in ufe, of a man lying at length upon the gunnel of the barge, and pawing the walls with his feet; in narrow boats this is ftill more evident, where a plank is obliged to be laid acrofs the barge for the men to lie down upon their backs, in order to be able to reach and paw the walls with their feet! The tunnel near Atcham on the *Shrewfbury* canal, though of 970 yards in length, has a towing-path through it; fo has one at Newbold on the *Oxford* canal, and many other fhort ones in different places. In all fhort tunnels, and even in long ones, if the ground proves, on examination, found and good for tunnelling, it certainly would be worth while to give the neceffary width to the arch, to admit of this effential appendage.

Among the moft confiderable tunnels that we have, are thofe at Worfley on *Bridgewater*'s canal, 18 miles in length! Marfden on the *Huddersfield*, 5280 yards; Sapperton on the *Thames and Severn*, 4300 yards; Penfax on the *Leominfter and Kington*, 3850 yards; Laplat on the *Dudley*, 3776 yards; Blifworth on the *Grand Junction*, 3080 yards; Ripley on the *Cromford*, 3000 yards; Dudley on the *Dudley*, 2926 yards; Harecaftle on the *Trent and Merfey*, 2888 yards; Norwood on the *Chefterfield*, 2850 yards; Weft-Heath on the *Worcefter and Birmingham*, 2700 yards; Morwelham on the *Taviftock*, 2500 yards; Oxenhall on the *Hereford and Gloucefter*, 2192 yards; Braunfton on the *Grand Junction*, 2045 yards, &c.

The longeft tunnels that have been propofed, befides the above, were one of 5 miles on the once propofed extenfion of the *Manchefter Bolton and Bury* to the Calder river; and one of 4¼ miles on the *Portfmouth and Croydon*, through the chalk hills fouth of the latter place. The towns of Manchefter, Kidderminfter, and Southampton appear to be tunnelled under by the *Bridgewater's*, *Stafford and Worcefter*, and *Southampton and Salifbury* canals refpectively.

The *executing of deep-cuttings* appears to have been long familiar to the Chinefe, fince we read of fome of their canals that are in places excavated 80 feet deep! and of others that are cut 20 feet deep for feven or eight miles in length! The fetting out and determining upon the flopes of a *deep-cutting* of confiderable depth and length, are objects deferving more of the engineer's attention, than has in too many inftances been beftowed upon them: the firft ftep, after the line and the level of the intended canal are determined upon, fhould be to examine minutely the foil in every part that is to be cut in, and to prove the fame by the finking of feveral fhafts; if any of thefe, towards the centre of the hill, fhould be found in loofe and porous foil full of water, while the ends of the intended cutting may appear to be in found ftuff; it will be worth while, in fome fuch cafes, to put down pumps and erect a temporary fteam engine, to pump up the water during the work, and to drive headings from fuch pump-fhaft, on one or both fides of the intended cutting, and below its bottom, as has been before mentioned, preparatory to driving a tunnel. Should the whole of the cutting appear to be in loofe alluvial ftuff, full of water, and difpofed to flip, or a part only of the ground at one end, as happened at the fouth end of the deep-cutting near Tring, on the *Grand Junction* canal, it certainly will be right to begin fuch part, by driving a heading up from a proper point below the intended cutting, and to give time for the fprings to drain off before the cutting is begun, which may afterwards proceed in feparate lengths at the fame time, and with much greater certainty and difpatch, by the help of crofs headings, to drain off the water, than is practicable without fuch precaution, unlefs expenfive and very powerful pumps or machines are ufed in the works to clear them of water in different places; while the tendency to flip is much increafed by fuch fudden and partial drawing off the water. *Slips* are among the moft formidable accidents to which canal-works are liable, and can hardly be too much guarded againft, by giving an extra flope to banks in fuch places, but particularly by driving headings behind fuch parts, fome time before the workings are begun, in order that the fprings may be intercepted, by which the moft porous and loofe ftuff like quick fands may, in many inftances, be converted to found and good ftanding ftuff. After all, where the *ftrata* alternate very faft, and have a confiderable dip, and any flippery matter like fullers earth or potters clay intervene, adjoining to a porous foil that can fupply it with moifture, it is almoft impoffible to avoid flips, that will prove moft difaftrous in their confequences, both in expence and delay of the works; as happened in the Tring deep-cutting above mentioned, on the *Gloucefter and Berkley* canal, and many others which we have heard of.

When the engineer has, by a thorough inveftigation, as above recommended, afcertained the nature of his ground, and its tendency to flip, he can determine what flope the upper banks A B and P K (*Plate I. Canals, fig. 6.*) ought to have in every part; for thefe ought not to be regulated by the flopes C F and I G, againft which the water is to lie, and the waves of the canal to act, but be as fteep as the ground or rock will ftand, in every confiderable length together; and the degree of the upper flopes will be liable to vary accordingly; if thefe are too much floped, a wafte of land and of labour in excavating and making fpoil-banks will be occafioned, while if they are made too fteep in flippery or loofe wet ground, flips may happen that will occafion ftill more ferious expences, and delay alfo. All thefe preliminaries being fettled, and the width in every part calculated, a number of flope-holes muft be dug at A and P, and a lock-fpit dug out to join them, by a careful workman, as mentioned before on the marking out of the canal; and the top-foil being removed and clamped, from a fufficient fpace for ftowing the ftuff, the work will then be ready for the contractors to begin digging. This will be our proper place to notice feveral machines, and contrivances for affifting the operation of excavating of canals, docks, or other deep-cuttings. The moft fimple and ufual method for fmall depths is by runs of wheeling-planks, fupported in an oblique direction up the fide of the bank upon horfing-blocks of different heights, on which the labourers wheel out the ftuff. In larger works, *turn-beams* or *horfe-gins* are erected on the bank, and a level-ftage or fcaffolding is erected over part of the deep-cutting; two ropes wind and unwind contrary ways off the drum or barrel of the gin, and pafs over pulleys fixed over the end of the ftage; thefe ropes terminate in three fmaller ones, two of which have at their ends

rings, and the other a hook, of iron. When a loaded barrow arrives on the run below the stage, a labourer stands ready to slip one of the rings on to each of the handles of the barrow, and to hook the other end into the fellies of the wheel; when the revolution of the gin draws up the loaded barrow to the stage above, which a labourer lands, unhooks the three ropes, and affixes them in like manner to an empty barrow that is to be let down, while a full one is ascending as before, by the other rope. The loaded barrows are wheeled away upon the stage, and run therefrom to any place above that is desired. At the *London Docks*, we saw a very simple method used; two strong posts were set fast into the top of the bank of the dock, at 40 or 50 yards from each other; and at about five or six feet high on each, a large common pulley or ship's block was fastened, by a short length of rope; through these blocks a strong rope was run, whose ends terminated in two smaller ones, with rings at their ends, as before mentioned: the length of this rope was so adapted, that one end reached to the bottom of a very steep run or plane of planks that were laid and fixed on the bank, pointing up to the post at top; while the other end was nearly at the top of another similar plane at the other post. At a proper place between the two pullies, the whipple-tree of a horse's harness was attached or lashed on to the rope. The operation was conducted, by a man arriving at the bottom of the plane with his loaded barrow, the wheel standing at the foot of the plane, the end of the rope being at the bottom of the plane, and the horse standing still near the post at its top; the labourer then slipped the two rings on to the handles of his barrow, and the horse being set in motion towards the other post, the barrow was drawn up the plane, and the man also with it, who made use of his feet, sustaining himself from falling backwards by holding fast by the barrow handles, which he at the same time was enabled to guide; when arrived at the top, and entered upon a plane there of less inclination, the horse had arrived almost at the other post; and while he was stopped, and was turned round ready to return again, by the boy who attended him, the labourer slipped the rings off his barrow handles, and wheeled the same away upon the upper run; another labourer instantly slipped these rings on to the handles of his empty returning barrow, and the return of the horse let him and his barrow down the plane again, the handles going first, and the man holding them as before, but with his back to the barrow; while the other ends of the rope were drawing another labourer and his loaded barrow up the other plane as before. The simplicity, dispatch, and perfect operation of this contrivance, do great credit to its inventor. In very considerable works, it will be attended with the greatest dispatch, as well as ultimate saving of expence, to use trams and temporary iron rail-ways; and if the height and quantity of stuff to be delivered at any one place be very considerable, inclined planes, with steam-engines of small dimensions, (such as are now every day manufactured and improved) should also be erected, to draw up the trams, as at the *London Docks* above mentioned. It is evident, that the simple and straight course for the horse, attached to the middle of a rope as above, may often be substituted for the expensive turn-beams above mentioned, particularly where dispatch in setting the apparatus to work is an object.

Mr. *Ralph Dodd* appears to have contrived a machine to be worked by men, by the means of levers, for excavating canals, which was tried in the year 1794, in the deep cutting at Dawley near Hayes on the *Grand Junction* canal. Mr. *Carne's* machine for the same purpose, but worked by a horse at length, appears to have been used in 1794, in the deep-cutting near Coston Hacket, on the *Worcester and Birmingham* canal. In the *Monthly Magazine*, vol. ii. p. 594, we have the following account of the operation of *E. Haskew's* patent excavator: "This machine takes the soil from the bottom of the canal, at 40 feet deep, with equal facility as at six feet from the surface! One of them is at work upon the *Gloucester and Berkely* canal. By the assistance of two men only, it removes 1400 loaded barrows from the bottom of the canal, to the distance of 40 feet, in 12 hours; and is so contrived, as to take up the loaded barrows, leave them at top, bring down the empty ones in regular rotation, and leave them at the bottom. It can be moved along the canal to the distance of 26 yards in 10 minutes, by the two men that work it."

In October 1793, Mr. *Joseph Sparrow* took out a patent for a machine, consisting of a box, with its bottom opening on hinges, suspended by a sort of universal gib or crane, the whole moving upon wheels; which he strongly recommends for elevating and discharging the soil dug out of the canal. See *Repertory*, vol. v. p. 77.

Among the most considerable deep-cuttings, are those at Ashton on the *Lancaster*, Tring on the *Grand Junction*, Coston Hacket on *Worcester and Birmingham*, Burbage on the *Kennet and Avon*, Little-borough on the *Rochdale*, Smethwick on the old *Birmingham*, &c.

The *construction of Locks* is so important a part of canal-making, and they are so very essential to the system itself, that we shall give some brief particulars of their history. Mr. *William Chapman*, in his "Observations on the various Systems of Canal Navigation," has devoted his 7th chapter to an account of the internal navigations of China, compiled from sir George Staunton's and other authentic accounts. He observes, that our pound-locks are unknown in China, (although explained to them by the French missionaries in 1685); and it appears from his account, page 76, that their grand or principal canal is, in fact, only a river or stream navigation, although greatly diverted by art from its ancient course in some parts; the current of the water being slow, and prevented from running off too rapidly by its descent being occasionally checked by flood-gates, consisting of two abutments of stone, one projecting from each bank, and leaving a space in the middle just wide enough to admit a passage for the largest vessels employed upon the canal; and to prevent unnecessary waste of water through the flood-gates, the passages are occasionally closed by planks let down transversely and separately one above another, their ends resting in a vertical groove in each abutment; and he observes, at page 89, that it was probably between the years of the Christian æra 605 and 618, that these were introduced. At page 87, he says: "The Chinese method of overcoming ascents appears to be long subsequent to the attempts of the Egyptians, under the successors of Alexander, who, according to Monf. Huet, bishop of Avranches, had the art of constructing sluices, or locks of one set of gates, so as to stop the impetuosity of the current, and be occasionally opened. Though termed gates, the openings were most probably closed with beams of timber, let down in grooves; as gates of large width and depth could not be opened without difficulty, even against a small difference of level. There are, however, such sluices with gates upon several of the running canals on the verge of the *Shannon*. They were erected about the middle of this century, (1750) and are of difficult use, because of the force requisite to open them. These running canals are on the Chinese principle, and nothing more than new channels for a portion of the river; which, when it is low, are stopped as in China, to retain a head of water sufficient to pass the boat." And

Mr. *Robert Fulton*, in his Treatise before quoted, page 7, says: "Machines similar to those of the Chinese have been erected in Flanders, on river navigations, when interrupted by falls, or shoal water; while another mode adopted has been, to erect a dam or wear across the river below the fall, in which were placed two strong buttresses of stone, with perpendicular grooves; after passing the boat above the buttress, a strong gate was let down the grooves, which stopped the water till it ran to a sufficient height to enable the boats to pass." This last description of Mr. Fulton, and which we have also seen in several other places, seems to come nearer to the invention of locks than the others above, which is the reason that we have inserted it, before finishing this subject from Mr. *Chapman*, who continues at page 88, and says: "These single pairs of piers of the Chinese, are properly called by De la Lande, half-locks. The casual position of two pair of piers near to each other, has, no doubt, occasioned the invention of locks; as it would soon be seen, when the gates or stop-beams of the lower piers were closed, and of sufficient height, that the water would be nearly still between the upper pair of piers, and afford an easy passage. On this principle, in place of single pairs of piers, two pair would be erected, sufficiently near to each other for the purpose, and capacious enough to hold a fleet of boats. It would soon afterwards be found, that in dry seasons the waste of water was greater than could be conveniently afforded, and the operation tedious for single boats; thus would progressively arise the invention of locks with walled chambers, and sluices through their gates or walls. There are at this day existing on rivers locks of the first construction, composed simply of two pair of piers, without any connection of walls or pavement between them." The *Kennet* and the *Lea* have unwalled locks. Here we may add, that Mr. *Thomas Telford*, when projecting the *Inverness and Fort-William* canal, on account of the great plenty of water and magnitude of the vessels that are to pass, proposed not to wall the locks the whole length, but to have earthen banks between the two pair of piers of masonry, that support the upper and lower gates of the locks. Mr. *Chapman* has suggested the paving of the concave bottom and sloping sides of locks, in similar situations.

It appears from M. *De la Lande*'s *Traité des Canaux de Navigation*, that the first lock was supposed to be erected in the year 1488, upon the *Brenta* near Padua; and that shortly after, the two canals of Milan, between which there was nearly a fall of 34 feet, were joined by means of six locks similar in principle to those at present in use. The first lock that *James Brindley* erected, appears to have been at Compton on the *Stafford and Worcester* canal; but they were not at that time uncommon in England on several of the rivers, and on the *Sankey* canal.

A *Lock* or *Pound-Lock* is the connecting part between the two pounds or reaches of a canal, that are upon different levels, and this part, called the chamber of the lock, can at pleasure be made to coincide, in the level of its water, with either the upper or lower canal. This is managed by means of two pair of doors or gates, one at each end of the chamber of the lock; in which gates, or through the side walls of the chamber, are provided small sluices or paddles, by which water can be let from the higher pound to fill the chamber to the upper level, the lower gates being close shut; or to empty the same to the level of the lower canal, the upper gates being close shut: by which means, supposing the lock *empty* (this term is often used, but it is not to be literally understood, since the lock, when said to be empty, has the same depth of water in its bottom as the lower canal has), and a vessel or boat arrived on the lower canal, there will be no difficulty in opening the lower gates, and entering the lock, because the water is level and at rest; when entered the lock, the gates are shut after it, and water is drawn from the upper canal by the paddles or cloughs, and in a few minutes the lock becomes full, the boat having risen with the water; when this is the case, the upper gates can be opened without difficulty, the pressure of the water being equal on both sides of them, and the boat can now move forwards on the upper canal. In this state of the lock, we have only to suppose another boat to enter from above, and shut the upper gates after it; when the upper paddles being close shut down, and the lower ones opened, the water will sink in the chamber, and the boat with it, until the lower gates can be opened, owing to the level of the water, and the boat can proceed forwards on the lower canal. The two operations which we have described are called *locking up* and *locking down*.

In *Plate* V. *Canals*, *figs*. 36, 37, 38, and 39, we have given a plan and sections of a lock. We have before observed, that the fall at each lock ought to be equal; and the locks ought to be all of one width and length, unless water be in great plenty, and any local trade of a particular kind may require them to be otherwise; because then, a barge in descending through a line of locks will require the same quantity of water at each lock, which we may suppose to descend with the barge, and there will be no water to discharge uselessly by the weirs, or required from feeders, by such a barge during its descent, as must happen in descending through a series of unequal locks. The upper gates of a lock (See the section, *fig*. 37.) stand on a weir, or wall, as *figs*. 36 and 37, across the canal, called the breast of the lock, and the place of this is to be fixed by the engineer before the workmen can begin to dig out the ground for the lock; which being done, an inverted arch, with a slight curvature, is turned very sound with bricks or good hewn stones, as a floor to the chamber of the lock, which, if the soil is porous, should have a lining of puddle under it, and should be worked into the side and breast walls: the foundation of these walls ought very carefully to be attended to, and if the ground is not very sound and good, piles must be drove, and the foundations of them secured in the most substantial manner. Instead of turning an inverted arch under, and for some distance within and without the lower gates, two rows, or more, if the soil is very porous or soft, of pile-planking, or dove-tail pikes, are to be drove across the bottom of the lock (as shewn in the sections by *l l*, *figs*. 37 and 39.); the length that these are to enter into the ground will, in a great measure, depend on the softness and porosity of the bottom. *Pile-planks*, or dove-tail piles, are stout pieces of narrow elm or oak planks, represented in *Plate* IV. *Canals*, *fig*. 30, each having a groove down its side to receive a thin slip of deal or other straight-grained wood, to break the joint, and prevent the water from getting through; the pile A is supposed to be the centre one, or that which is first drove, and is sharpened at bottom by a bevel on each side for that purpose, and shod with iron, if that precaution shall appear necessary; the other pile-planks B, C, D, &c. that are drove in succession, are sharpened to a double wedge, but instead of the acute angle being square to the pile, it is bevelled to about 45°, by which the pile B will be forced close to the pile A as it is drove, and the pile C to B, &c.; by which, and the slips or tongues afterwards put down the grooves, an impenetrable barrier is formed to prevent the water from soaking and softening the

foundation, and at length undermining and blowing up the lock-gates and walls. The heads of the pile-planks ſhould be ſawed off very ſmooth and true after they are drove, and a croſs bearer or ſleeper is to be nicely fitted to them, and firmly ſpiked down: other intermediate and parallel ſleepers are to be fixed down upon the heads of bearing-piles drove for that purpoſe, and the whole is to be covered, after the intermediate ſpaces are cloſely filled up with bricks and cement, by very ſound and nicely jointed planks, that are called the *ſheeting* of the lower gates, as ſhewn in the plan, *fig.* 36, and ſection, *fig.* 37. Upon this ſheeting the lock-ſill is to be fitted and ſtrongly fixed down; if the canal is wide, or the fall of the lock conſiderable, this ought to be compoſed of two pieces of oak timber, each abutting againſt the hollow quoins at one end, and meeting at the other in an angle towards the head of the lock, as in the plan, whence ſuch are often called mitre-ſills. A ſimilar precaution is to be uſed on the breaſt of the lock, by driving a row or more of good long pile-planks, with croſs pieces or ſleepers, and ſheeting for the upper gates, on which the lock-ſills are to be laid; as alſo a ſtout piece of wood, cut to the curve of the breaſt-wall of the lock, to which it is to act as a coping, to prevent the keels or ſtems of the barges from damaging the ſame. It is uſual to ſet out the foundations of the lock-wall ſtraight and parallel to each other, (excepting the wing-walls or return-walls at the end to keep up the earth, and connect with the ſloping banks, in the upper and lower canals) and when theſe walls are arrived at the height of the floor of the chamber, and ſheeting of the lower gates, then to begin to batter them back to give them greater ſtrength. On the *Derby* canal we found the locks 90 feet long between the gates; the bottom line of the foundations ſtraight, and exactly 14½ feet apart; as the walls riſe they are gradually battered between the gates to 15 feet apart; and in the middle between the gates to 15½ feet, ſo that the coping of the walls of the chamber of the lock are curved three inches towards the back; and all the beſt modern locks are conſtructed on ſimilar principles. Hollow quoins, which are large hewn ſtones, having a regular curved ſpace cut out of one of their angles, are worked into the walls for the gates to work in, inſtead of hinges, as ſhewn in the plan, *fig.* 36: if good durable free-ſtone is difficult to be procured, the hollow quoins may be compoſed of very large bricks made in proper moulds for the purpoſe; and in large works, a large piece of caſt iron of the proper ſhape to work into the wall, is ſometimes uſed inſtead of quoin-ſtones or bricks, as at the *London Docks*. The tops of all the walls, locks, bridges, or other erections of a canal, ought to be coped with hewn and well jointed ſtones, and cramped together; or with large and well burnt bricks of the proper ſhape, having their top angles rounded off, and ſet in good cement. Proper buttreſſes of cloſe maſonry ſhould be made to the walls of the lock behind, to give them greater ſtrength, and to tye them more effectually into the bank, and to break the regularity behind, ſo that if water ſhould leak through the walls in any particular part, when the locks are filled, or allowed to ſtand full longer than is proper, ſuch water may not connect together in a large extended ſheet, to act by its hydroſtatic preſſure in overturning or bulging in the walls, of which we have read and ſeen ſo many inſtances. A proper ſpace behind all the walls ſhould be puddled, allowing each courſe to ſet effectually before another is applied; and proviſion muſt be made, in carrying up the walls, for crooked culverts, each of 14 to 20 inches or more in diameter, according to the ſupply of water and dimenſions of the lock, called the paddle-holes, to extend from near the floor of the chamber of the lock, behind the walls, and riſing up, ſo as to return into the lock again behind or above the upper gates; its plan being ſhewn by dotted lines *ee*, in *fig.* 36, and its vent, or lower end *e*, is ſeen in the ſection, *fig.* 37, as its mouth or upper end is in the ſection, *fig.* 38; in the latter caſe, one of them being ſhewn open, and the other cloſed by its paddle or clough. A receſs is made in each wall above the ſeveral hollow quoins, large and deep enough for the gates to open back into, and remain out of danger from barges paſſing into or out of the lock, as ſhewn in the plan, *fig.* 36. In the receſſes belonging to the upper gates, a weir or over-fall, *ii*, *fig.* 38, for the water, is provided, four or five feet long, having a coping or ſill of good ſtones or bricks, juſt the height at which the water is intended to ſtand in the upper pound or canal; theſe are called the *paddle-weirs* or *lock-weirs*; a large flat ſtone is uſually laid over theſe, leaving three or four inches in height for the ſtream of water, to complete the wall upon, and the cavity is conducted down, diminiſhing in width and enlarging in depth behind the walls of the lock, into the paddle-hole, or crooked culvert before mentioned. The conſtruction of the paddle-holes and weirs deſerves the particular attention of the engineer, to ſee that they are conſtructed of the very beſt bricks, laid in good cement, and the ſame allowed to ſet thoroughly before the canal is filled; or the rapidity, and frequent action of the water in theſe parts, will wear, undermine, and endanger this part of the lock.

We may proceed now to deſcribe the other appendages of the lock; theſe are the lower gates, which ought to be conſtructed of ſtout oak framing, the head or hinge poſt of the gate being rounded and nicely fitted to the hollow-quoins above deſcribed, while the other heads are carefully chamfered off, ſo that when the gates are ſet up in their places, touching the hollow-quoins, and the mitre-ſills, their chamfered heads ſhall meet and truly fit; inſtead of hinges, either a rounded part of the head of the gate, or a ſtrong gudgeon of iron at the bottom, is let into a hole provided in the ſtone or timber below, but not fitted thereto ſo as to bind, or prevent the rounded part of the head from being preſſed cloſely and uniformly into the hollow-quoin by the force of the water; the top of the gate is kept in its place by a ſtrong ſtrap of iron which goes round it, allowing ſufficient ſpace, and is keyed or ſcrewed down to a ſtrong cramp or pin in a large ſtone, which acts as a coping to the hollow-quoins. The gates are uſually planked with deal, ſometimes upright, but often in a diagonal direction; and a ſquare hole is left in the boarding of each lower gate, to which a paddle is adapted, with its ſtem or rod riſing up above the top of the gate, by the ſide of a ſtandard of wood, *k*, *fig.* 39, fixed to the top rail or balance beam of the gate in which is a pinion, working into a rack of caſt iron on the paddle-ſtem, which is turned by a winch-handle, and the paddle is retained at any height to which it may be drawn, by a ratchet or ſtop, that can readily be turned up to lock into the teeth of the rack, or turned down to diſcharge and let down the paddle. The top piece or balance beam is uſually a tree of conſiderable dimenſions, having its full ſize, or but end, left unhewed to act as a handle to turn the gate round by, and at the ſame time to balance it, ſo that the front of the gate may not drag on the ſheeting at bottom; but as it would be very difficult thus to balance large lock-gates, like thoſe at the *London Docks*, a roller of braſs or caſt iron is fixed under the head of each gate, and a ſtrong circular ſill of wood, or rail of caſt iron is prepared on the ſheeting, for the ſame to roll freely

upon, and cause the gate to open and shut easily: the height of the roller above mentioned is made adjustable by a screw, so that the gate can at all times be kept from dragging on the sheeting: and instead of handles to open such gates, ropes and chains, and capstans, erected on the banks for the purpose, are used to open and shut them. The upper gates are hung and constructed nearly like the lower ones, except that they have no paddle-holes in them, and are usually boarded no higher than the level of the paddle-weirs behind them, in order to assist as weirs in carrying off a superfluity of water; but these are often attended with bad consequences, the fall of the water wearing, and in time damaging the breast of the lock; and in floods, the stream or splashing of the water may damage goods in, or even endanger the sinking of, heavy laden boats, in the lock; the same may also happen with deeply laden boats when the paddles are drawn in ascending, if the paddle-holes do not enter the chamber of the lock at some distance below the surface of the water, and in a proper direction: on the *Monmouthshire* canal the paddle-holes are both united, and discharge themselves through the breast of the lock into the chamber; a practice that seems by no means worthy of imitation. The upper paddles, or those behind the upper gates, are drawn by a rack and pinion, *k*, *fig.* 38, by means of a winch-handle, (which each bargeman and lock-keeper carries with him) in the same manner as those in the lower gates, which we have described above. Guard-rails or curving pieces of timber, *f*, *fig.* 36, ought to be strongly bolted on to piles driven for that purpose in the front of the wing-walls just above the surface of the water, to guide the boats into and out of the locks, without striking the walls; which is far preferable to the huge stones let into the wing-walls in some places, called bumping stones, and calculated rather to break and destroy the barges, than protect the walls. It will be necessary also to provide a strong piece of wood formed to the curve of the breast-wall of the lock, *b*, *fig.* 37, before which it should be suspended a few inches above the water when the lock is empty, by means of two or three chains; these are called bumping pieces, and are intended to receive the stem of the boat, and prevent it striking the wall when the same is not strapped or stopped in proper time; a practice, however, for which the bye-laws or clauses in the act should provide adequate fines or punishments: and strapping posts should be set firmly into the ground in the proper places for the bargemen to wind their rope, or strap as they call it, and by easing it out by degrees, to stop the velocity of the boat before it arrives at the gates or breast of the lock that it is entering. The gates should also be furnished with two or three strong upright planks on the lower side, *g g*, *fig.* 39, to receive occasional blows from the noses or stems of the boats, and prevent the planks of the gates being broken or started thereby. There is room for the skill of the engineer to be exercised, in forming the lock-sills and gates to that particular angle which will render them stronger for the same width and depth of lock, than they would be if they met more acutely, or were shorter and met more obtusely. In very large and wide locks, the gates should not be straight or plane, but a little curving to give them greater strength. On narrow canals, it may not be necessary to make double or angle gates, but one gate shutting square across the lock may be strong enough to answer every purpose, and be opened more readily than two gates on the opposite banks can be; the upper gates in particular, on account of the comparative shallowness of the water there, may be single, while the lower gates, if the fall is considerable, may be double. In setting out canals, where the fall of the ground is very gradual and easy, it may be necessary to avoid long lengths of deep-cutting below, and of embanking above, or making the line very crooked, to make shallow locks, if water is plenty; and under the same circumstances only, will it be allowable to make 10, 12, or more feet locks in particular places, however well the ground may suit the same; many of these double locks were at first erected, as on the old *Birmingham* canal, and the *Calder and Hebble* navigation, where about 1783 single locks were obliged to be substituted, to avoid the waste of water, before pointed out.

We have not yet noticed an inconvenience and waste of water, which attend the placing of locks nearer to each other than about 100 yards, or having basons between them, equal in area to about that length of the canal, as was done at Salter Hebble in 1783 in the alteration above mentioned; without which precaution, a boat in descending lets down more water than the pond below will hold, without raising its surface so as to lose a good deal over the lock-weirs, and still worse happens in ascending, for the short pens are so much lowered by filling the lock below, that laden boats are unable to proceed for want of water, until a supply is let down to waste, through the upper lock, to help them forwards. As many locks as can conveniently be brought near to each other, on the principles above, and before explained, should be contrived, if it can be done, to be in sight of each other, and of a length of canal each way; and the lock keeper's house should be so placed, that he can when at home at his meals, or otherwise, in bad weather, see barges approaching the locks, in time to meet them before they enter the locks. Mr. *Fulton* who wrote in 1796 says, that the cost of locks for 25 ton boats, was about 70*l.* per foot rise, and for 40 ton boats, about 100*l.* per foot rise; this may serve to give some general idea of the cost of locks at that time; but we would observe, that the decrease of the value of money, and the exceptions to all general rules on these subjects are so many, no dependence ought to be placed on such modes of estimating. If sufficient water-way is given in the paddles, and there is assistance enough to draw both the paddles, and open and shut the gates at the same instants, a boat may pass each lock of the usual construction and rise, in three minutes time, but in general, $5\frac{1}{2}$ minutes will be nearer to the average time lost at each lock, as observed by Mr. *Bevan* on the *Grand Junction* canal. Theorems for the time of filling a lock of given dimensions, and with given paddles and fall of water, should be found and compared with many experiments on the locks under the care of our resident engineers. (See *Nicholson's Journal* 8vo. N° 9, vol. iii. p. 30.) It should be considered, that a boat going up lets down or consumes twice the weight thereof (boat and cargo included) in water, more than in going down through each lock; for the boat on entering the empty lock, expels as much water into the lower reach as its own draft of water, which is made good out of the upper pound when the boat enters the same; while a descending boat expels its own flotation bulk of water from the full lock into the upper pound, where it is retained on the shutting of the upper gates; the mean of a passage each way will be a lock-full for each boat, unless they go always loaded one way, and empty the other. Mr. *Fulton* says, that the consumption of 25 ton boats through eight feet locks, will in general be about 103 tons of water in ascending, and 103 tons in descending; and Mr. *Chapman* informs us, that boats passing and repassing a summit, laden one way, and returning empty, will require nearly 13 times the weight of their lading of water for their lockage, out of the summit

pound. Seven hundred tons of lading per day are as much as pass or repass upon any one of our canals, according to Mr. *Fulton*.

We cannot with propriety quit the subject of constructing locks, without mentioning *coffer-dams*, which are a double range of piles drove very close to each other in a circular form round the mouth of any canal or dock, that is to have a lock built, repaired, or altered, connecting with the sea, a river, or any existing navigation that cannot be emptied of its water; the interval between the piles being filled with earth, the water in the space between the coffer-dam and the intended works is then pumped out for the works to proceed; the many and fatal accidents to which these are liable, especially when the works are nearly completed, and the earth is excavating from the bottoms to open the passage freely to the lock or works, require all the precautions, skill, and attention of the most able engineers, especially when the rise and fall of the tides or waves of the ocean, present unequal action on the piles and dam.

The *saving of water in the use of locks* is a consideration of so much importance in most of the instances which occur, that it is necessary we should mention several of the expedients which have at different times been proposed, or practised for that purpose. Some of the most obvious of these are, a minute attention to the fitting of the gates and paddles, constructing every part of them of the most seasoned and durable materials, with the utmost precautions against partial wear or liability to accidents, by which the gates or paddles would leak and waste the water; and should such leaks happen, the establishment for working the canal ought to be such, as to detect the same immediately, and apply the proper repair or amendments without delay. It is of great importance to adapt the plan or surface of the water in the lock, to the size of the boat or boats that are to be used, leaving as little water uncovered in the chamber of a lock as possible, and for this purpose, where water is scarce, it will be necessary to enforce the regulations, that the act ought to contain for the length, width, and form of the boats that are to be used; and on canals for large and small boats, to see that two or more of the smaller boats are so contrived as to lie close together in the lock, and occupy the whole space thereof as one of the large boats would do: less than this number of small boats must not, when water is scarce, be allowed to pass, or without paying such increased tonnage or lock dues, as will act like a prohibition.

The *waiting for turns*, particularly by empty or lightly laden boats, ought also to be provided for, and it may be necessary on some occasions to enforce the same; viz. to suffer no boat to pass down, until there is another arrived below, and ready to ascend as the lock is filled; or any boat to ascend, till another is ready above to descend with the same lock-full of water. Where small or short boats are in pretty general use upon a canal, as on the *Shrewsbury*, it may be right to adopt the practice which Mr. *Thomas Telford* has described, who says, "the locks are so formed as to admit of either one, three, or four boats passing at a time, without the loss of any more water than what is just necessary to regulate the ascent or descent of the boat or boats that are then in the locks. This is accomplished by having gates that are drawn up and let down perpendicularly instead of being worked horizontally; and each lock has three gates, one of which divides the body of the lock, so as to admit of one, three, or four boats at a time." See *Plymley's* Report before quoted, page 2 . .

A very sensible writer, who has given a full account of the *Grand Junction* canal, in the *Agricultural Magazine* for 1803, vol. viii., under the signature of a constant reader, suggests at page 204, the propriety of an additional set of narrow locks on each side of the summit which is in want of water, for the use of the narrow boats, to which they should be exactly fitted; as also, to avoid the expence of lifting or pumping water, that can be collected in reservoirs or feeders at some distance below the summit level, by using shallow locks of only three or four feet rise each, between the summits and the points where such waters can be taken in without lifting. The pumping of water from a lower level to supply the waste of lockage, by means of steam engines, has been practised with success on the old *Birmingham*, the *Barnsley*, and several other canals; the *Croydon* was to be constructed with a dependence on this mode of supply, as appears by its act; and on the *Grand Junction*, engines have lately been erected near Tring and near Braunston, for raising water to the summit-levels. A very considerable power is lost in the descent of the water through the paddle-holes, to fill the lower part of a lock, and again through the gate paddles in emptying the upper part of the lock; we have often thought that it might be practicable to apply this power for returning a certain quantity of water into the upper pound, either by making the descending stream act on a wheel, or on vanes like those of a smoak-jack, or by means of hydrostatic pressure, or momentum machines. See *Monthly Magazine*, vol. vi. page 124.

Side-ponds are an expedient for retaining part of the water, from the upper part of a lock when it is to be emptied, and to use the same towards filling the lock again for the next boat: they are said to have been invented by M. *Dubie*, and one with 3 divisions was tried in a lock of 20 feet fall, on the canal of *Ypres*, near 100 years ago; they are described by M. *Belidor*. On the 5th July, 1791, Mr. *James Playfair* took out a patent for this mode of saving water in using locks. See *Repertory*, vol. iii. 303. And in the same work, vol. i. p. 377, Mr. *W. Pitt* has described three side-ponds, in form of sectors of a circle. We read that in April last, (1805) an experiment was made on the *Grand Junction* canal, and two of these side-ponds, with earthen banks like a canal, and each about the same size as the lock, were tried near Berkhamstead; into one of them, whose bottom coincided with about half the height or altitude of the lock, the upper quarter of the water of the lock, for a descending boat, was drawn, and it was there retained by a close shuttle; the shuttle of the other side-pond, whose bottom was about level with one-fourth of the height of the lock, was then opened, and about another quarter of the water in the lock flowed into it, and was there retained by the shuttle: the remainder being emptied by the gate-shuttles into the lower canal; and the boat having passed out, and another ascending one taken its place in the lock, the side-pond that had last been filled was emptied into the lock, and then that also which had been first filled; these together filled half the lock, before the upper paddles were drawn to fill up the remainder, the shuttles of the side-ponds being first shut down; by this means, two boats were passed, by letting down only half a lock-full of water into the lower pound; and the lock remained full, ready for another descending boat, as before. The time taken up by the above operations was about nine minutes for each boat that passed, or $3\frac{1}{2}$ minutes more than if the side-ponds had not been used. We understand that side-ponds are becoming common on different canals; their construction offers a very curious exercise for the abilities and skill of the engineer, so to apportion the number, size, and height of the ponds, that, consi-

dering the expence of construction, loss of time in passing, and the saving of water that is effected, the result may be the most advantageous.

It appears, that Mr. *Michael Logan* took out a patent in 1804, for raising or forcing water into a lock; also, that in January 1791, Mr. *Joseph Brooks* obtained a patent, for a method of drawing up the false or moveable bottom of a deep side-pond or large well near a lock, and by that means filling the lock with water, until a barge had passed up, or another was ready in the lock to descend, when the false bottom being again let down, the water retreated by the same connecting culvert that had brought it into the lock, it was again emptied, and the boat able to proceed on the lower canal, without having wasted or let down any water. See *Repertory*, vol. vii. p. 361.

Mr. *Lawson Huddleston* has communicated, through the medium of *Nicholson's Journal*, 8vo. vol. iv. p. 236, a method of raising the water in a lock, from a deep side-pond or well as above, by means of a solid or heavy plunger that can be let down into the well, by means of machinery that suspends it, when the water is to be raised, and drawn up when it is to be allowed to sink again; the plunger being balanced in all its different degrees of immersion by a counter weight acting on a snail or spiral curve.

Mr. *Robert Salmon* has invented a different mode of accomplishing the same thing; his plunger being hollow, and as buoyant as possible; and for forcing the same down into his cistern or side-pond, when the lock is to be filled with water, he has contrived a very curious apparatus; it consists of a very heavy carriage on four low wheels, or heavy rollers of metal, connected together by a frame to answer the same purpose. Two frames or planes are prepared, that turn on fixed centres, as a door does on its hinges, but horizontally instead of vertically; the other two ends of these planes rest on the two ends of the plunger, by means of uprights therefrom and moveable joints; upon these planes the carriage rolls, in such a manner, that when it is drawn forwards, by means of a rope or other machinery, the weight advances upon the plunger, and the planes being at liberty to turn on their joints, it sinks the plunger by degrees, until at length the four wheels rest exactly over the joints at the ends of the plunger, exerting the whole weight of the wheels and carriage, to keep it down and elevate the water in the lock; on the carriage being withdrawn, the weight on the plunger lessens, and it rises, until at length the four wheels rest just over the hinges or fixed joints, and no part of the weight of the carriage or wheels is then exerted upon, or to counteract the buoyancy of the plunger, and the water retreats from the lock into the space under the plunger. That this carriage, which must be extremely heavy for large locks, may not be subject to run forwards or backwards on the planes; Mr. *Salmon* has contrived one of them with a peculiar curvature or bend, so that the tendency of the carriage is as great to advance as to retreat, in every part; and a constant and small weight, hung on the end of a line over a pulley, in the model, will cause it to move either way, with a regular and steady motion. During the last session of the *Society of Arts*, in the *Adelphi*, Mr. *Salmon* presented a model and description of his invention, for which he was honoured with a premium; the model is lodged in the Society's collection, for public inspection, and a particular description of the same is expected to appear in their next, or 23d volume of *Transactions*. Mr. *Salmon* has hit upon a method of mechanically constructing the *curve* above-mentioned for one of the planes, which is found to approach very nearly to the arc of a circle. A mathematical friend of Mr. *Salmon*, who was shewn the model in an early stage of his experiments thereon, has proposed as the 84th question in *Leybourn's Mathematical Repository*, the determination of the nature of the curve in a particular application of Mr. *Salmon*'s principle; we are sorry, however, to see this question still unanswered by the ingenious correspondents of that very useful and learned work; because this curve promises to be applicable on several occasions in the construction of hydraulic machines. We have been treating of various contrivances for saving water in the use of locks of the common construction; and we shall now proceed to mention several substitutes for locks in overcoming ascents on a canal or river, but in which the boat continues floating in water; before we proceed to inclined planes, or other schemes, in which the boat is to be drawn or suspended out of the water, or the goods to be removed by cranes, &c. to other boats.

Substitutes for locks, have been called for in some situations by the actual scarcity of water, in others by the previous and necessary appropriation of the whole of the streams to mills or the practice of irrigation, and not in a few cases by the jealousy and opposition of mill, park, and land owners; the intemperate zeal also of some projectors may have operated, who do not hesitate to prognosticate the annihilation of lock-canals, by "improved science; in like manner as improvement in machinery renders the old apparatus useless." See *R. Fulton's Treatise*, page 28 and 110, *&c.*: also, *W. Chapman's Observations thereon*, page 2, &c. Several canals have, like the *Haslingden*, been restricted from erecting locks in particular places, without the mill-owners' consent; it is therefore no matter of surprise, that various schemes have been proposed to obviate the necessity of common locks. On rivers where the boats are hauled up against the stream, it is not unusual to lighten a boat by shifting part of its cargo into other boats, called lightening boats, so that their diminished draft of water may enable them to be dragged over any particular rapid; and in more extreme cases, the whole of the lading may be taken out, and be conveyed by land to meet the boat again after it has been dragged empty over the rapid. Rapids may themselves often be made navigable by jetties, or contraction of the width of the stream in such places, and if the fall is rendered very considerable thereby, capstans or machinery may be erected for the hauling up or easing down of boats; these methods have doubtless been in use from the earliest periods; and we read of great numbers of men in China being employed with ropes to haul boats up their artificial rapids or falls. The methods of using stop-planks occasionally to cause an artificial flood in Egypt, China, Flanders, and Ireland, as before-mentioned (when speaking of the invention of locks), are also very ancient, and such are still in use upon several of our rivers; on the *Ivel* river below Biggleswade, we think we remember seeing upright narrow planks used against a moveable beam at top of the water, and a fixed sill at the bottom of the same, for penning the water and producing a flush or flash of water, when the planks are removed and a boat is to pass. On most of our old river navigations there are gates erected to pen the water, and the same are drawn up to occasion a sudden flash while a boat is to pass. At the entrance of the Worsley mine on the Duke of *Bridgewater*'s canal, we remember a large door that was drawn up for our boat to pass under it into the tunnel, and then let down to pen the water therein three or four inches higher than it stood in the canal. The difficulty of opening large gates, to produce a flush of water or to let a boat pass

has been before noticed; and in the *Memoires de l'Acad. des Sciences* for 1707, we find the defcription by *M. de la Hire* of gates calculated to obviate this inconvenience in part, by having a large pair of doors in the gates opening the contrary way, or with the ftream, which on the drawing of a pin can be let to open by the preffure of the water; after which the great gates can be opened with eafe, and when open, the doors can as readily be fhut again and pinned, owing to their ftanding in the direction of the ftream; and the gates then are ready to be fhut again as foon as the head of water is run off, or the boat has paffed. It appears, that in extending the navigation of the *Seine* river in France, gates were introduced, which the Duke of *Rouanez* had invented, and which are defcribed in the *Memoires de l'Acad. des Sciences* for 1669, confifting of two upright gates, rather wider than half, and as deep as the channel of the ftream or river, bent into the arc of a circle of about 48 feet radius; to each of thefe gates feveral long beams of wood were fixed, meeting in or near the centre of the circle, of which the gates formed a part; and here being firmly united, they abutted againft a folid pier of ftone, or worked on a centre-pin fixed in a ftrong pile, drove very firmly into the earth by the fide of the channel, at 48 feet below the place where the gates were intended. A notch was formed in the bank of the channel on each fide, in form of fectors of circles, fufficiently large to contain the two gates and their beams or centering as above. By this conftruction, the whole of the preffure of the gates when fhut and the water penned by them, was brought to act on the two upright pins or centres; and a very moderate force applied to the head of each gate would draw them apart and into the fector-like receffes prepared for them, leaving the channel or courfe of the ftream perfectly free of any obftacle, to check either the current or a boat in paffing through. By a fmall adjuftment of the places of the centres, gates of this kind may at all times be made to fit clofe to each other in the centre of the channel, on its bottom, and alfo to the fide walls of the channel above them, and yet on being moved a fmall fpace from each other they may clear thofe walls and be free to move into the recefs, in the bottom of which there may be fmall rollers to carry the gates with lefs friction, or rollers under the gates may be ufed for the fame purpofe. See *Jacob Leupold's Theatrum Machinarum*, folio, publifhed in 1726 at Leipfig.

Dr. *James Anderfon*, of Edinburgh, has contrived, and publifhed in 1794, in his *General View of the Agriculture, &c. of the County of Aberdeen*, a method of elevating or depreffing fmall boats, floating in a coffer or large tight open cafe full of water, that can at will be made to coincide and connect at one of its ends with either the upper or lower canal; into or from which the boats may pafs without the lofs of more water than is neceffary to fill the narrow fpace between a draw-gate at the end of each canal and at the ends of the coffer, when the fame is preffed and retained clofe to the end of the canal, and a fmall additional quantity to reftore the equilibrium and give motion to the coffers, of which there are two exactly of fimilar dimenfions fufpended and connected together by ftrong chains. *Mr. Chapman's* concife defcription of this invention is fo much to our purpofe, that we beg to ufe his words, who fays, "the doctor there obferves, that, for all the purpofes of commerce, no more width of boat is requifite than four feet, or more than two or three feet depth; and that the length might be indefinite, fo as not to be inconvenient for afcending and defcending between any two levels of canal, which he propofes to be done in the following manner, viz. that the lower level be run up to nearly under the end of the upper, and terminate by an upright end and two fide walls of mafonry, to the full height of the fall, with a pier in the middle dividing the paffage between the two fide walls into two openings of rather greater width than the boat; the two ends of this pier are to be elevated fo as to fuftain the axis of a wheel, of a diameter equal to the width of the pier, and half of each opening. A chain paffing over the wheel fufpends from each end a rectangular cafe, fo hung, that when one fhall be at the bottom ready for a boat to float into, the other fhall be at the top, and clofe preffed to the wall or frame at the end of the canal, fo as to prevent the efcape of water; then, by opening a ftop-gate at the end of either canal, and another at the correfponding end of the cafe, it is obvious that the boat may float in or out. The lower boat and cafe (or cafe with water only) are then in a kind of lock juft containing the cafe, and of fufficient depth to permit it to defcend to the level of the lower canal. From this lock there is a conduit to keep the water down below the canal bottom. Thefe are the outlines of the invention, which, where the connection between the two levels is a precipice, or fo fteep as to require only a fhort tunnel to the well or pit, up or down which the boats are to move, may, on receiving fuch improvements as it is capable of, be eafily carried into effect for fmall boats, for which the author alone propofes it. It is obvious that under other circumftances, as to fituation, the expences of high embankments above, of deep finking below, and of bringing up the conduit to lay dry the lower locks, muft more than counterbalance any advantage than can be derived from it." Where the fall is confiderable, the doctor has propofed a balance chain, of the fame weight per foot as the fufpending one, to be hung from each coffer or cafe. See *Repertory*, vol. ii. p. 21.

On the 24th December, 1798, Mr. *James Fuffell* took out a patent, (fee *Repertory*, vol. xi. p. 7.) for a method differing in principle from that of *Dr. Anderfon* above defcribed, only in having an axle and *two* wheels thereon, at a diftance from each other on the middle pier, and under his coffers or receptacles, fimilar axles with a pair of wheels, and inftead of his coffers or receptacles being fufpended from the two ends of a chain paffing *over* the wheel, as in *Dr. Anderfon's* method, *Mr. Fuffell's* two chains are fixed to the tops of the fide walls, paffing *under* the wheels of his receptacles, and over the wheels and axle on the middle pier. He alfo defcribes rollers or guides by the fides of his lock-pits to fteady the receptacles, and a toothed wheel on the middle fhaft or axle connected with a fly or brake wheel to regulate the motion of the chains and receptacles; he alfo propofes the gates or hatches at the end of his receptacles, to be balanced by counter-weights, and to draw down into a cavity prepared for the purpofe, when a boat is to be paffed in or out, inftead of drawing up. And if the fall be very confiderable, he fuggefts the propriety of a fhort tunnel or arch to conduct the lower canal into the lock-pit, inftead of an open notch or perpendicular walled cut in the hill for the lower canal. It appears that this balance-lock of *Mr. Fuffell's* was put in practice, or at leaft tried, on the *Dorfet and Somerfet* canal, near Froome, on the 6th of September, and 13th of October 1800, on a 21 feet fall, and with boats of ten tons burthen; delays in completing the above canal, and forming a communication, prevented this lock from being made ufe of for a long time afterwards; but we believe that the note of a late writer on the above experiments, ftating that a fubfcription was fet on foot in 1802, to raife money to make a lock in this very place, originated entirely in miftake.

On the 18th of March, 1794, Meffrs. *Rowland* and *Pick-*

ering, took out a patent (see *Repertory*, vol. i. page 81.) for a coffer or cradle similar to those described in *Anderson's* and *Fussell's* methods above, but which, instead of being suspended from or on chains, is, in this method, supported on pillars by a large diving-chest or caisson, sunk in the water of a pit or well underneath, the whole being so balanced, that the cradle can be brought to coincide either with the upper or lower canal, when boats are to be floated in or out of the same. *Mr. Chapman*'s short description of this invention is as follows: "Messrs. Rowland and Pickering's plan of enabling great boats to ascend and descend with inconsiderable waste of water, consists in having at the head of the lower level of canal, a pit sunk as much below the bottom of it as the difference of height between the two levels, added to the depth of a covered caisson of requisite magnitude. This caisson, when immersed in the water, with which the pit is filled to the level of the bottom of the canal, is to support on wooden or iron pillars, of height equal to the fall between the two levels, a trough or cradle with gates or draw-doors at each end, containing a sufficient depth of water, to which the floating power of the caisson must then be in equilibrio, and consequently capable of moving with ease between the top and bottom of the pit. When the surface of the water of the cradle is level with either of the canals, and the end of it is closed against the framing of the gate of the canal by screws or other means, and the water let in to fill the vacancy between the gate of the cradle and that of the canal, they both may then be opened, and a boat be admitted to pass out. Excepting what may if necessary be used for regulating the equipoise and change of motion; the intermediate water between the gate of each level and that of the cradle, is all that is consumed, and with draw-doors to the cradle and single gates to each level as already premised, the quantity must be very trivial. The weight of water displaced by the bulk of the pillars sustaining the cradle need not be material; and where requisite, it is proposed to be counterbalanced by weights acting on a spiral wheel. This plan, which possesses ingenuity, and is applicable in many instances, is now carried into execution on the *Ellesmere* canal, near Ruabon, in Denbighshire, on a fall of 12 feet, and for boats of 70 feet length and 7 feet width; the whole is moved up and down by a rack and pinion towards each end of the machine." We may add, that *Rowland and Co.*'s patent describes four ropes to be attached to the corners of this cradle in some instances, passing over pullies in a framing above, to which weights are to be suspended for assisting the buoyancy of the caisson, or even in some instances to supersede its use altogether, in balancing and moving the cradle up and down. The three methods last described, as the inventions of *Anderson, Fussell*, and *Rowland and Co.* are called *Balance-locks*.

On the 19th of June, 1792, Mr. *Robert Weldon* took out a patent, (see *Repertory*, vol. ii. page 235.) for a *Caisson-lock*, consisting of a long covered and close caisson or trunk, with close shutting doors at its ends, in which water enough is contained for a boat to float into it, when it coincides with the surface of the water of the upper canal; when being shut in, this caisson or diving-trunk containing the boat, is to be sunk through a deep pit to a door or valve opening to the lower canal, and the end of the caisson being fixed closely and exactly against the opening of the same, it, as well as the door of the caisson, is opened and the boat passes out into the lower canal, and the apparatus is then ready for another boat to enter and ascend in like manner. Mr. *Chapman* thus describes one of these caisson-locks for a fall of 45 feet, and for boats of 72 feet length and 7 feet width: "The caisson or chest is cylindric, and in this instance of sufficient strength to bear the pressure of a column of water 45 feet or upwards, to which it is subjected when opposite the lower level, on account of the necessity of its being covered when opposed to the entrance of the upper level. It is so balanced, that when it has sufficient water within it to float a boat, it is of the same specific gravity as the medium it floats in; and, like an air balloon, it ascends or descends by a slight increase or diminution of its relative gravity, which, in this machine, is done by raising out or admitting an inconsiderable quantity of water. The pit in which the diving chest moves, has, opposite each level of canal, a tunnel or opening closed with gates, and is so much higher than the upper canal as to contain a height of water just sufficient, as already mentioned, to cover the caisson when opposite the upper level. In this or in its lower position, when run close to and abutting against the entrance, it is retained by the water being let out of the short part of the tunnel between the gates of the level and the end of the caisson. It is then held there by the pressure of the column of water intervening between the surface of the water and that of the canal to which it is opposed. The gates of the level of the caisson are then opened, and the boat goes in or out, and on the gates being again closed, and the water let into the vacancy, the diving chest is ready to proceed to the other level. This scheme possesses much originality, and may often be usefully applied." The patent describes racks and pinions, or chains and pulleys, for regulating the motion of the caisson in its ascent or descent through the water, and describes the gates of the upper and lower level of the canal, as sliding up into proper recesses by the motion of a rack and pinion, when the caisson by settling opposite it, has removed the pressure of the water in the lock-pit, and that pumps are to be used by the boatmen, who are shut up in the caisson on board their boat, for expelling or admitting water to lighten or weight the caisson, and air-pipes to prevent accidents by the want of fresh air, in case of any delay while the caisson with the men in it are under water. It appears, that the first of these caisson locks was erected in 1794, for an experiment, by the side of the canal at Oken Gates in Shropshire; and that about August 1796, one was begun in Combe hay, on the Dunkerton branch of the *Somerset coal* canal, having the fall and dimensions above described; about December 1797 it was completed, and was several times tried and boats and men passed through it, among whom was Mr. *William Smith*, the resident engineer; the trials continued occasionally during the spring and part of the summer of 1798, the canal not being ready for its being used by the trade; when it was discovered, that the walls of the lock pits had not been constructed with the requisite care by the contractor and inventor under whose directions they were built, but the water had got behind them, and on drawing off the water to make some alterations, they bulged so much, that the whole was rendered unsafe and useless. After which the company substituted inclined-planes for removing coals, &c. in boxes to other boats at this place; but since which, locks have been constructed in their place.

Before we quit those contrivances in which a boat and its lading are to be transferred floating in water, we have to mention an ingenious suggestion of Mr. *William Chapman*. He proposes, (*Observations*, p. 85.) that a caisson containing water and a boat thereon should be drawn *side-ways* up a steep inclined plane, to be counter-balanced thereon by weights, or water-tubs descending down pits prepared for that purpose, or by another similar caisson on another plane. We find also in Mr. *Jo*[illegible] *Fussell*'s patent (*Repertory*, vol. xi. p. 12.) the menti[illegible] caissons with boats floating in

them, being raised and lowered by the double chains of his particular construction, on double inclined planes, wheels, axles, &c.

The *construction of Inclined Planes*, on which boats are to be drawn up or let down from one level of a canal to another, appears to have been long known in China. Between the upper and lower levels of their smaller canals, a double glacis of smooth hewn stone is constructed; the principal slope of this extends from the bottom of the lower canal to a little above the surface of the water in the upper canal, and terminates in a large beam of wood across the plane, the top of which is rounded and made very smooth, from which another similar plane of stone descends to the bottom of the upper canal. The bottoms of their boats appear to be flat, and constructed so strong and smooth, that a boat and its lading can be dragged up one of these planes. and lowered down the other, in order to pass forwards on the canal. The amazing populousness of China rendering manual labour very cheap, men are employed in incredible numbers for working their canals; a rope is said to be hove round the stern of a boat that is about to ascend one of these planes, and by means thereof she is dragged up the plane either by hauling directly at the rope, or by passing its ends round capstans erected for the purpose on the banks of the larger planes, to the bars of which the men apply their strength. When the boat is brought to an equipoise on the cross-beam, another rope is dextrously flung round the head of the boat by means of which it is eased or let down without violence into the upper canal; the same process is used in descending. It seems a matter of doubt, whether cradles or rollers of any kind are used under the bottoms of the Chinese boats, while they are passed over their inclined planes, as the latest accounts of travels through that surprising country, make no mention of such. Water-wheels have also been described by some as in use there, for raising and lowering their boats, instead of capstans worked by men; but of this also there are perhaps reasons to doubt.

The *Ponts aux Rouleaux*, or rolling bridges, which are particularly described in a tract printed at Paris, in *1693*, are said then to have been practised for some time in Holland with success, particularly on the canal between Amsterdam and Sardam. This kind of inclined planes had rollers at short distances, over which, by means of a water wheel, the boats were hove up to the ridge separating the two waters, a little higher than the upper one, and were launched or let regularly down to the other. Mr. *Chapman* observes, that the boats in this and the Chinese method, could not be very long, because, although here in ascending or descending the inclined plane, they might bear upon many rollers; yet, in the change of position from the regular line of ascent, they must obviously bear upon one roller, and be liable to strain.

Mr. *Davis Dukart*, an engineer in the Sardinian service, was, as Mr. Chapman informs us, (*Observations*, p. 5.) the first who introduced inclined planes into practice in the British dominions; he resided in Ireland for some years previous to 1777, and was engaged in the Tyrone collieries near Dungannon, which are situate about three miles distant, and 200 feet above the level of the canal connecting with Lough Neagh; the sums granted by government being inadequate to the construction of locks for so great an ascent, Mr. *Dukart* turned his attention to small boats and inclined planes, of which he constructed three, connected by narrow canals. The falls were 70, 65, and 55 feet, which last terminated about 15 feet above the canal; to which, by a short rail-way, his boats, again floating over a carriage, were drawn onwards to the wharf; and there, being supported on geers and frames, the boats were turned over to discharge their cargoes. This first attempt differed from the *Pont aux Rouleaux* in no other respects than having a double passage down the inclined planes, so that by means of a rope leading over a wheel, his loaded boats drew up his light ones; but finding various inconveniences, from some of the rollers not turning, and from the individual irregularities of the diameters of others throwing his boats to one side, as well as from other causes; he suggested and put in use an inclined plane with two parallel rail-ways; up and down which, by the aid of a rope passing over a wheel at the head of the plane, his boats alternately passed, upon a cradle with four wheels, over which his boats were floated at each extremity of the fall. The loaded boat (the trade being a descending one,) drew up an empty one; for drawing the boats out of the upper canal on to the ridge, terminating the descending plane, he used a horse-gin. A few boats only were thus passed, by way of trial, before the works were suspended, and Mr. *Dukart's* death happening soon after, all of them were laid aside, and since that period a rail-way has been substituted instead of the canals and inclined planes.

Mr. *Edmund Leach* contrived an inclined plane in the year 1774, five of which he recommended to be used on the *Bude and Launceston* canal, and two of them on the *Liskeard* canal, (see his *Treatise on Inland Navigation;*) he also presented a model of his inclined planes and apparatus, to the Society of Arts, in whose repository, in the Adelphi, it may be seen by any person. This contrivance consisted of a double inclined plane furnished with rollers, from the bottom of the upper canal upwards to a ridge or cross beam, then of a short platform or level part, from which the same kind of double inclined plane, except that these were without rollers, descended into the lower canal for a considerable depth. On each of these inclined planes, a cradle or frame for receiving the boat upon rollers in an horizontal position was placed; and under this cradle was fixed a large water-tight chest or caisson, with a valve in its bottom and an air-hole at top, so that when the cradle and chest were let down into the lower canal the chest filled itself with water, to act as a counterpoise, and regulate the motion. These chests were of such a form, that when the cradles on the tops were in an horizontal position, the sides of the chests adapted themselves to the inclination of the planes, and they had several rollers fixed in their sides to lessen the friction in moving up and down the planes: to the upper corner of this chest a strong frame was hung with hinges like a door; this frame had rollers fixed on both sides of it, and was so contrived, that when the chest and cradle were ascending the plane with a boat upon them, this frame rested on the inclined plane, and prevented by its rollers any friction from the head of the boat against the plane; when the boat had arrived at the top of the plane, this moveable door fell into an horizontal position, and just covered the platform above-mentioned, when the boat was at liberty to be moved forwards on the rollers of the cradle and door, by means of a rope and capstan, to the cross beam, and from thence it could by the same means be lowered easily down upon the rollers of the upper plane into the upper canal. The two chests and cradles above described were connected by means of strong ropes, which wound round an horizontal axis fixed in a strong framing above the top of the planes, so that one of the cradles would always be sunk into the lower canal just deep enough for a boat to float on to the cradle, at the same time that the other chest and cradle were at the top of the other plane, and its door lying on the platform as above described. A water-wheel was to be provided, with cog-wheels connecting with

the axis or barrel for the rope, to give motion to the ropes and cradles with their contents, when a sufficient quantity of water had been let into the upper chest by a valve and pipe contrived for the purpose, or out of either of the chests by means of a string attached to their valves, till an equilibrium of the two chests, cradles, and boats upon them were obtained. By this apparatus it was proposed, that in general one boat should be ascending upon one of the planes while another descended on the other; but the caissons were large enough to admit of sufficient water from the upper or lower level being taken into one of the chests, to balance a loaded boat on the other. The capstan worked by men was proposed to be used, for dragging boats out of the upper canal over the upper plane and platform on to the cradle in order to descend. Walking-wheels, to be worked by men, were also proposed instead of water-wheels, where the water was very scarce in the upper canal. The canals above-mentioned were never carried into execution, although an act of parliament were obtained for the former, nor have we heard of any of Mr. *Leach*'s planes being brought into actual use.

Mr. *William Reynolds*, of Ketley, in Shropshire, was the first who contrived and executed an inclined plane (which was completed in 1788) for the passage of boats and their cargoes, which was found fully to answer, and continued in practical use. Mr. *Thomas Telford* has thus described the same, in *Plymley*'s Agricultural Report of Shropshire, p. 291. Mr. Reynolds "having occasion to improve the mode of conveying iron-stone and coals from the neighbourhood of the Oaken-gates to the iron-works at Ketley, these materials lying generally at the distance of about a mile and a half from the iron-works, and at 73 feet above their level, he made a navigable canal," called the *Ketley* canal, "and instead of descending in the usual way, by lock, continued to bring the canal forward to an abrupt part of the bank, the skirts of which terminated on a level with the iron-works. At the top of this bank he built a small lock, and from the bottom of the lock, and down the face of the bank, he constructed an *inclined plane*, with a double iron rail-way. He then erected an upright frame of timber, in which, across the lock, was fixed a large wooden barrel; round this barrel a rope was passed, and was fixed to a moveable frame; this last frame was formed of a size sufficient to receive a canal boat;" these boats were 20 feet in length, 6 feet 4 inches wide, 3 feet 10 inches deep, and each carrying 8 tons; "and the bottom upon which the boat rested was preserved in nearly an horizontal position, by having two large wheels before and two small ones behind, varying as much in the diameters as the inclined plane varied from an horizontal plane. This frame was placed in the lock, the loaded boat was also brought from the upper canal into the lock, the lock-gates were shut, and on the water being drawn from the lock into a side-pond, the boat settled upon the horizontal wooden frame, and as the bottom of the lock was formed with nearly the same declivity as the inclined plane, upon the lower gates being opened, the frame with the boat passed down the iron rail way on the inclined plane into the lower canal, which had been formed on a level with the Ketley iron-works, being a fall of 73 feet. Very little water was required to perform this operation, because the lock was formed of no greater depth than the upper canal, except the addition of such a declivity as was sufficient for the loaded boat to move out of the lock; and in dry seasons, by the assistance of a small steam engine, the whole of the water drawn off from the lock was returned into the upper canal, by means of a short pump. A double rail-way having been laid upon the inclined plane, the loaded boat in passing down brought up another boat, containing a load nearly equal to one-third part of that which passed down. The velocities of the boats were regulated by a brake acting upon a large wheel, placed upon the axis, on which the ropes connected with the carriage were coiled." It appears that this plane has an inclination of about 22°, except near the extremities, where it diminishes to about $11\frac{1}{2}°$; and that about 400 tons of coals usually descend thereon daily. In 1789 a copper medal, or halfpenny, having a representation of this plane on one side, and of the cast-iron bridge at Coalbrook-dale on the other, was struck, and issued by the Coalbrook-dale company. Since the practicability of inclined planes has been established, by the success of the Ketley plane, but few acts have been passed for new canals, without a clause authorizing the company to erect inclined planes, instead of locks, if they should be found most advisable. Before proceeding to mention the inclined planes of different constructions, which have been since made or proposed, we shall notice the under-ground plane at Walkden Moor, which was completed in October 1797, upon *Bridgewater*'s canal, it being so similar to the Ketley plane above described.

The *Duke of Bridgewater*, in the year 1800, caused an account to be presented to the Society of Arts, in the Adelphi, London, of the inclined plane which he had erected and brought into use, under the direction of his agent, Mr. *Benjamin Sothern*, between two different levels of his tunnels or subterraneous canals from Worsley near Manchester; for which the Society voted his grace their gold medal, and published plans and sections, and an account thereof, in their 18th volume of *Transactions*; to which we refer, only mentioning, that this plane, which is $35\frac{1}{2}$ yards high, and 151 yards long, through an inclining tunnel hewn in the solid rock, at near 60 yards below the surface of the ground, differs from the Ketley plane, in having, upon about 57 yards of the lower end of the plane, a single rail-way only, to or from which the two rail-ways above join by easy curves, to proceed up to the locks by one rail-way, or down by the other. A winch and pinion are provided, to be occasionally worked by two men, into cogs in the large brake wheel, for setting the boats in motion. Rollers are placed between the iron rails, for the slack part of the great ropes to run upon, and for further preventing the wear of these ropes, they are lapped round with a small cord. About 12 tons of coals are let down in each boat, and a boat and cradle on which it runs, weigh about 9 tons more. About 16 minutes is consumed in passing a pair of boats: the boat-cradles are 30 feet long and $7\frac{1}{3}$ feet wide, moving on 4 iron rollers. A small bell gives notice from the bottom to the top of the plane, when the boats are placed on the cradles, and the machine ready to work. The water of the locks is let down by a paddle, through a perpendicular shaft, to the middle canal, and acts as a water-bellows to force fresh air down into the extensive tunnels and works that are on the lower level. The upper gates of the locks turn in hollow grooves like a common lock, but the lower gates draw up in grooves, by means of windlasses, to let the boats pass out or in when the water is let off.

Mr. *William Reynolds* has the honour of introducing another sort of inclined planes, on the *Shropshire* canal, where there are three planes in use of 120, 126, and 207 feet rises! The act for this canal passed in 1788, and it was completed, under the direction of Mr. *Henry Williams*, as resident engineer, and opened in 1792. These planes are upon the same construction as those at Ketley, except that there are no locks at the top of the descending planes, but the same are continued above the surface of the water in the upper canal, and terminate in a cross beam, from which another plane and rail-way descend into the upper canal: this is for

avoiding the waste of water which locks at the top of the planes occasion. A small steam engine is used for working the axis of the rope barrel, at some distance from which, on the upper side, there is a large pulley or wheel, fixed at a proper height, for the great rope to pass over, to draw the boats up or let them down the long descending plane; another smaller axis and rope barrel are provided, which can, like the larger one, be cast in or out of the engine-geer at pleasure; this last is used for hauling the boats up the short ascending plane, from the upper canal. The engine can also be used to draw empty boats occasionally up the long plane, in case such want to pass, when there are no loaded ones ready to descend, and draw them up, as we have before described. The wheels or rollers under the cradles appear on these planes to be equal in diameter, and not of different sizes, so as to bring the two ends of the boat to a level, as on the *Ketley;* they do not, therefore, appear applicable to very steep planes or to long boats. On the windmill plane, which is 600 yards in length, and 126 feet rise, six boats have been passed down, and six taken up within the hour, the steam-engine and three men only being employed: the boats here are of the same length and breadth as on the *Ketley*, but shallower, so as to carry but five tons; and such boats are said to be passed down these planes for three pence each, and the empty boat taken up gratis. At Wombridge on the *Shrewsbury* canal, Mr. *Thomas Telford* has since erected a plane, 223 yards in length, and 75 feet rise, exactly on the same construction as the above, of which an account, with plans and sections, may be seen in *Plymley*'s Report, p. 294.

On the 18th of June, 1793, Mr. *Joshua Green* took out a patent for the use of double inclined planes and rail-ways, on which cradles for the boats are to be used, consisting of a frame of wood, and the bottom corded by strong ropes across each other like the common bedsteads, that the boat may not be strained; in order to introduce wheels of four feet diameter for the cradle to move upon, a strong frame is to surround the cradle, and be firmly bolted to it, but leaving an interval sufficient for the four or more wheels to move between it and the cradle, by which the axles can be fixed to the wheels, and work in gudgeons at each end, with less friction than common wheels or rollers. To his brake-wheel hand-spokes are adapted, for men to assist in setting the machine in motion, instead of a winch as before described on *Bridgewater*'s; the ropes are to be capable of adjusting to the proper length as they stretch or contract, by a screw or otherwise. A third inclined plane is directed to be made, for the purpose of carrying a counter weight or vessel, whose rope is to pass over another axis with a brake and hand-spoke wheel, for hauling the cradles and boats out of the upper level to the ridge or cross beam, or to ease them down into the same. He recommends spare vessels laden with water to be in readiness to pass up or down the opposite plane, as a counterpoise to any single loaded boat that may arrive at the plane. Also that single planes, and with less inclination, may in some instances be adopted. See *Repertory*, vol. v. p. 11.

Earl Stanhope, in the year 1793, in recommending the *Bude and Hatherleigh* canal, proposed, between the different ponds or water-levels of the intended canal, to have iron rail-roads of gradual and easy ascent, on which boats of two tons were to be used, suspended between a pair of wheels of about 6 feet diameter, and to be drawn up or let down the same by a horse, in order to be launched in the upper or lower water-level or canal.

On the 8th of May, 1794, Mr. *Robert Fulton* obtained a patent for the use of a double inclined plane, whereon cradles having cisterns or caissons under them, no ways different from Mr. *Leach*'s above described, except that the boats were in some cases to be taken on to the cradles *side-ways* instead of length-ways; this was proposed to be accomplished by short inclined planes, on which the boats, upon wheeled carriages, were to be dragged out of the upper and lower canals by means of ropes working on the axles of water-wheels; a brake is to be used for regulating the motion of the boats and cisterns, when brought nearly to an equilibrium by the valves; brace-blocks, or pulleys, to be used for shortening or lengthening the large ropes when necessary. See *Repertory*, vol. vii. p. 222.

Mr. *William Chapman*, at page 85, of his Observations, which were written principally in answer to Mr. *Fulton*'s treatise, suggests this *side-way* motion of boats on inclined planes, as before-mentioned, not knowing, as we apprehend, of Mr. *Fulton*'s patent above-mentioned, because it was not published till 1797; and it is indeed singular, that Mr. *F.* should, in 1795, have written 144 quarto pages on the subject of canals, and not once have given a hint of his having taken out a patent in the year before for some of the principles therein explained, and so highly recommended; nor does his long letter in the *Star* Newspaper of the 30th of July 1795, announcing this work being in the printer's hands, make the least reference to his patent. The Board of Agriculture must, we are confident, have been equally in the dark, in March 1796, or they would not have given Mr. *R.* the opportunity of puffing into notice, a subject wherein he was a patentee through their means. We beg here to remark, that our duty, in treating this part of our subject, seems to require the mention of all the inventions and methods which have come to our knowledge; and though we should have more pleasure in making known the inventions of those who lay the same at once open to the community, yet, as all of these will be so in a few years, we have not thought it right to exclude or be less particular in the mention of, inventions or contrivances so circumstanced: but to give the dates of such patents wherever we could, that their termination (at the end of 14 years) may be known.

Mr. *Robert Fulton*, in his 4to. work, entitled a "Treatise on the improvement of Canal Navigation," published in London in 1796, with many plates, has proposed the use of narrow canals and inclined planes, on which small and shallow rectangular boats are to be used, having low *wheels*, or rather trucks fixed underneath their bottoms; he proposes to have on his double inclined planes, an endless chain passing up the track of one plane and down the other, round or over wheels that are of the proper size and fixed in proper places and directions at top and bottom of the planes to suit the swag or curvature of the leading chain; these are made to revolve at pleasure, with power sufficient to drag a loaded boat up one of the planes, (by means of a short double chain belonging to the boat which is to be hooked into, and will at the proper time discharge itself from the leading chain), by means of toothed geer attached to the upper wheel, on which there are stubs to prevent the chain from slipping; which connect with a water-tub descending in a perpendicular shaft, discharging itself at bottom by means of a valve, and returning again to the top, when cast out of geer, by means of its counter weight, balance-chains, and fly, ready to be again charged with water from the upper canal. The motion of the whole is regulated by a pair of fanners or an expanding fly; a smaller axle and cog-wheel are provided, working into the tub-shaft geer, when necessary to draw the boats up a short plane that descends into the upper canal, on to a bridge or

curving top which unites the two planes, a ftop being provided to retain the boat in its proper pofition, while this laft chain is difcharged, and the boat-chains are hooked into the leading chains as before mentioned. When a defcending boat happens ready to draw another up, or a fingle one requires to be let down, the tub geer is to be caft off after the boat has been dragged on to the bridge thereby, and the fanners are to be trufted to for eafing it down. Mr. *Chapman*, who reviews this fyftem, juftly objects to the fmallnefs of the boat-wheels, and recommends that larger ones fhould be ufed in a water tight cafe or groove in the floor of the boat. Owing to the endlefs chain, Mr. *Fulton* fays, that during part of the defcent of a boat, the power thereby acquired may draw another boat out of the upper canal on to the bridge; and a boat may in fome cafes be kept ready in that fituation to begin the work; or, he propofes a common windlafs tooth and pinion to be ufed for that purpofe. For protecting delicate goods in his boats, he propofes a frame above the boat for fupporting the leading chains; and for transferring light timber that is too long for his boats, he propofes rafts to be made with a carriage under them, having wheels like thofe of his boats, by which thefe rafts are to be conveyed on the inclined planes. A totally defcending trade will not require the tub-fhaft, tub or its geer; and the fame may be added without interrupting the trade, when at any future time it fhall become an alternate one.

Mr. *Fulton* next defcribes (page 71.) his fingle inclined plane for great heights; here, his wheel-boats are to afcend and defcend on the fame rail-way on his plane; the leading chain winds round a barrel or drum, that can, by means of geer that cafts in and out, be moved with two different powers and velocities, by a water-tub working another barrel at the head of an upright fhaft as before defcribed; or the tub-fhaft geer can be entirely caft off, for the tub to afcend, or for a boat to defcend on the long plane, regulated by a brake or fanner as before mentioned. Mr. *Fulton* propofes his leading-chain, wheel or barrel, to be fo placed over the bridge between the upper and lower planes, and with a roll or fmall drum below it, that the leading chain hooked to one end of the boat may drag it out of the upper canal on to the bridge, and lower it down from thence without unhooking, and the fame in afcending. Mr. *Fulton* (at page 76.) propofes for fmaller rifes, inftead of a tub-fhaft, tub or its geer, to erect an overfhot water-wheel, to be fupplied from the upper level, with proper geer, and a drum for one end of a chain to wind round, the other, after paffing over two pulleys at the head of a plane, (one pulley would anfwer better, by placing the water-wheel or its drum oblique to fuit the fame) to be hooked to the ftern of the laft of three or more boats that are to afcend, each of the boats before it being in like manner hooked by their own chains to the leading chain, according to the weight of the boats, and the power of the water-wheel; when water is let on to the wheel, thefe are to be dragged up, and difcharge themfelves one by one, and flide down into the upper canal; boats are to be dragged up, fingle or more than one, out of the upper canal on to the bridge, and when they begin to preponderate towards the defcending plane, the water is to be ftopped from the wheel, which is to be allowed to turn backwards, and act as a fly or regulator to the velocity of the boats in their defcent. The water-wheel will not often admit of being fupplied from the lower level, as Mr. *Fulton* has fuggefted, on account of the great expence or the impracticability of a drain or fough to difcharge its water; the fame difficulties, as Mr. *Chapman* has obferved, attend feveral of the tub-fhafts which Mr. *Fulton* has propofed, for the perpendicular lift of boats from one level of a canal to another, of which we fhall treat hereafter. At page 37, and fig. D, in his 5th plate, Mr. *Fulton* has recommended his wheel-boats, to be ufed, on a fingle afcending plane to a coal-pit mouth, to be drawn up the fame by a chain winding on a drum, worked by the mine-engine, and lowered down the fame by means of a brake attached to the drum.

On the 2d of Auguft 1796, Mr. *John Luke* took out a patent for an inclined plane, on which boats in a cradle are to be drawn up, by the defcent of a water-tun on another plane, affifted by a water-wheel in certain parts of its motion, or in fcarcity of water, by a hand winch. See *Monthly Magazine*, vol. ii. page 651.

Mr. *William Chapman* recommends an improved kind of inclined plane in his *Obfervations*, &c. of which he has given an account at page 96., "by making the defcending and afcending way continuous, like Mr. *Fulton*'s; and having a lock at the head of the defcending way, long enough to contain a feparate carriage for three or four boats (or fo many as form what has been called a conjoined boat). Thefe boats, on defcending, would draw another gang light, or half loaded upwards, over the top of the ridge, no lock being requifite on that fide. The chief objections to this, lie in the vaft weight of a gang of boats, which, in a fteep angle of defcent, would require a very heavy rope, and in the difficulty of returning the carriages to their proper place. The latter may be got over by keeping the two ways at a little diftance, and joining them above and below by a femicircular rail-way for the carriages; coupled to each other (in fuch a way as to fuit the different boats that are to reft upon them, and yet admit of the neceffary extenfion, when the boat came over the concave part of the inclined plane, which may be affected by a worm fpring) to run along under water, after they have parted with their veffels. Both in this and the method laft defcribed, the water contained in the lock may be drawn off into a refervoir, at the head of the inclined plane; in this refervoir, or a pond communicating with it, may be fixed a broad underfhot water-wheel between the two rail-ways, to retard the motion of the defcending boats and throw back the water. This wheel may run in a clofe cafe, and be divided round its periphery by different fhroud boards, forming fo many wheels that one or more portions of its width may be employed at the fame time in throwing up water according to the neceffity of the cafe, to be determined by the velocity of the defcending boats, which by means of a centrifugal regulator" (the flying-balls or governor ufed in Bolton's engines, windmills, and other machines,) "will open one or more of the penftocks to let water below the wheel, or fhut them all as occafion may require. The refervoir under the wheel fhould of courfe never be exhaufted, but when drawn down to a certain extent fhould by a floating weight or any other method let in water from the head canal. Thefe means will anfwer for a defcending trade, and if the afcending trade be more that the other can draw up and water be deficient, recourfe may be had to a fteam-engine."

We have thought, that a different kind of lock at the top of an inclined plane might be ufed with advantage, compofed of a rectangular box, water-tight, except one end, which fhould be open, and having wheels under it of different heights, fo as to fupport it upon the plane in an horizontal pofition, its fize being juft fufficient for a boat to float into it. The end of the upper canal fhould terminate in a fingle lock-gate, the outfide border or edges of which fhould be leathered, or covered with lift; fo that when the carriage or cradle above defcribed is drawn up to the top of the plane, its open end fhould fix itfelf againft the lock-gate opening, in a water-tight manner, by means of wedges or fcrews prepared for the purpofe of confining it; a fmall fhuttle in the lock-gate might then be opened to admit

water to fill the cradle, making it act as the chamber of a lock; the lock-gate being opened, a boat might enter the cradle, from which it would expel great part of the water into the upper canal again, if the boat and cradle were nicely adapted to each other; the lock-gate and shuttle should be again shut, when the water might be drawn off into a cistern, (to be returned if necessary by a water-wheel or any of the methods before mentioned), the cradle be unfastened from the lock, and be let down the plane by any of the regulators before proposed. For passing the boat out of this cradle at the bottom of the plane, the back or other end of the cradle might open, or, perhaps a better method would be to continue the plane deep enough into the lower canal, that the cradle, which should in this case be heavy enough to sink in water, might descend low enough for the boat to float out or in, over its end; side rails should, in this case, stand up from the cradle, to shew its place when under water, and for guiding and fixing the boat over it, with liberty to sink into the cradle, as it is drawn up the plane to the surface of the water.

Mr. *Chapman* informs us (page 7.), that for avoiding the friction of the gudgeons of rollers, when charged with the weight of a loaded boat on an inclined plane, *Earl Stanhope* has proposed, that rollers between the boat's bottom and a smooth plane should be used, moving or rolling with the boat, for half the boat's length; the rollers then to return to their places by means of weights acting over pulleys, and connected by a chain to the ends of each roller. Mr. *Fulton*, he says, proposes to use moving rollers, attached to, or going under and through the cradle that contains the boat, the gudgeons at the ends of the several rollers being passed through the links of an endless chain or collar, by which the rollers are returned in a cavity under the boat, that is resting in the cradle; this endless chain of moveable rollers for lessening of friction, appears to be claimed as part of *A. G Echardt's* patent of the 31st of January, 1795, for various machinery: see *Repertory*, vol. ii. p. 365.

The principles of setting out canals, where inclined planes are to be used, are similar to those we have explained, in recommending several locks to be brought together to form a set of such, or a considerable fall in one place; it will, however, be necessary, in determining the place for an inclined plane, to choose ground which slopes as regularly as possible between the intended upper and lower levels; if any part of the ground for the intended plane is springy and disposed to slip, the springs must be cut off by effectual and durable under-drains. It will be better so to contrive the plane, if practicable, that little, if any, filling up of hollows shall be necessary in forming the plane, to avoid new made ground, which on a considerable declivity would perhaps slip, after heavy rains had saturated it with water; the foundations for the stones or bearers must also be carried through such new made ground, and into the firm-stuff. The stuff which is removed in forming an inclined plane, should be carefully levelled, or disposed of in holes, so as not to form spoil-banks, and be covered with the top soil previously taken from those places. In case a perpendicular shaft and sough thereto is wanted at the head of the plane, the knowledge of the *strata*, or matter which compose the hill, may be of considerable importance, in determining the best place for the mouth of the sough; which may not always be the nearest point at the proper level, to the intended shaft, if the *strata* or measures of the hill are various and dip considerably. The plane being formed of a sufficient width on the ground, a strong framing of timber braced across may be used, if good and durable hewn stone is not in plenty, fixed firmly down to a sufficient number of piles drove into the ground, the interstices between the framing being filled with good rubble stone, or gravel rammed very tight down. On these frames two or four sils or rails of sound oak, according as the plane is to be single or double, should be laid parallel and at the proper distances from each other, and firmly bolted down; and on these the slips or ribs of iron are to be evenly and smoothly fixed, for the wheels of the boat, or boat-cradle to run upon, and upon which they are to be confined from getting off sideways, by a rib standing up for that purpose, either upon the wheels or on the rails. If good stone is in plenty, it will be proper to cover the whole of the plane with ashler or well jointed stones, taking care that the courses across the plane at proper intervals are formed of large stones let some distance into and firmly bedded in the ground; and to these the cast-iron rails (that are used on good and durable planes) may be fastened by pins cast into a hole with lead. Or, if wooden rails are to be used instead of cast-iron ones, strong sleepers of wood should be worked into the paving of the plane at proper intervals, on which to bolt and fasten down the rails. Care should be taken, in all works of this kind, where large or hewn stones are used, to let no part of the mortices or holes which are cut in such stones remain open or unfilled with lead or cement, to prevent the rain filling them with water, which would in winter time expand with the frost, and in most instances split the stone. It is unnecessary for us to point out to experienced engineers, the great care and precaution which ought to be used in works of this nature, to make every thing substantial and more than sufficient to sustain the weight or strain to which it will be subjected, and which ought in most cases, particularly the moving parts, to be previously calculated, and before the apparatus is put together for actual use, every rope, chain, framing, wheel, &c. &c. should be subjected to a greater strain than can occur in practice, to avoid the unpleasant, and perhaps fatal accidents, which might otherwise happen, by which a prejudice might at the onset be excited against the scheme, so powerful as to cause it to be laid aside without proper trial. It would much exceed our limits to enter fully into this subject, we shall therefore proceed to those other contrivances for overcoming ascent on canals, where boats have been lifted out of the water, or proposed so to be, by a perpendicular ascent; after which, there will still remain to describe those methods which require the shifting of the cargoes of boats into other boats, or to rail-way waggons, &c.; first mentioning that on the *Shrewsbury* canal, an inclined plane is used for passing the boats over part of the ascent, while locks are used for the other parts; and Mr. *William Chapman*, at pages 54 and 99 of his *Observations*, &c. recommends whenever coals in large quantities, lime, lime-stone, or other minerals, are to be conveyed along canals, or are brought in by branch canals on a small scale, there being a scarcity of water which reservoirs cannot remedy, where it can be done in setting out the canal, in addition to the locks, to overlap the levels in a steep place, and communicate them by an inclined plane for boats (or a double rail-way for tram-waggons) leaving the lock communication to answer all the general purposes of commerce. The same author observes, that the porterage of articles from one level to another, and carriage of the boat itself is still practised in various parts of North America, as the falls of the Mohawk, from the Mohawk to Wood Creek, at the falls of Orandaga, &c.; also at several places called Tarbets, in the Highlands of Scotland, as in Cantyre, Loch Lomond, Arrachar and Long, Jura, &c. Among the principal inclined planes for boats, are those of Hay, Windmill-hill, and Wrockardine-wood on the *Shropshire* canal, Walkden Moor on *Bridgewaters'*, Ketley on the *Ketley*, Wormbridge on the *Shrewsbury*, &c.

On the 8th of May, 1794, Mr. *Robert Fulton* took out a

patent, as before-mentioned, in which he describes (see *Repertory*, vol. vii. p. 227.) either a rectangular upright notch in the steep face of a hill, to the top and bottom of which the two levels of a canal are brought, or a large perpendicular shaft and tunnel at the bottom for the lower canal, through which notch or shaft boats are to be drawn up or let down, in a pair of water-tight cradles, suspended at the two ends of strong ropes of chains, that are to pass over pulleys fixed above the top of the shaft, and connecting with a brake-lever or wheel, to regulate the descent of a boat in one cradle, and ascent of another in the other, after they have been brought to an equilibrium by the letting out or in of water by proper valves. The boats are to be drawn into and out of the cradles, by short inclined planes, in the upper and lower canal, on which the boats on wheeled carriages are to be drawn by ropes winding on the axis of water-wheels, to be turned by water let out of the upper canal thereon; brace-blocks are to be used for adjusting the length of the great rope, and capstans may be used instead of water-wheels, for passing the boats on and off the cradles. Mr. *Fulton*, in plates 11 and 12 of his "Treatise on Canal Navigation," and his descriptions thereof (pages 97 and 100) has more fully described this method; and proposes for a descending trade, that the full boats should draw up the empty ones, and instead of inclined planes for getting the boats on to the cradles, a cage of iron should be used, into which the boats on the lower canal can be floated; and for discharging them into the upper canal, he proposes two lock-carriages, or large water-tight boxes, open at one end, moving on iron rail-ways, and which can be advanced by racks and pinions over the shafts, while the boat is suspended high enough to clear its bottom; the open end of this lock-carriage is made to fit, and be retained against the frame of a lock-gate at the end of the upper canal, (as in Dr. *Anderson's* and *Fussell's* methods, and the water-tight cradle which we have lately mentioned), when the water being admitted by a valve, to float the boat in the lock-carriage, to the level of the upper canal, the lock or draw-gate thereof is to be opened, and the boat floated out of the cage to proceed on the upper canal; to the pulleys or drum-wheel over which the chains act, a fly or fanners is proposed to be connected to regulate the motion; as also an axis with cranks to work pumps, by which the water that is drawn off again from the lock-carriage into a side reservoir may be pumped up again into the upper canal, that no water may be lost. For an alternate trade, to which it may be at first adapted, or the necessary parts applied afterwards, an additional shaft must be sunk, in which a water-tub is to be suspended, instead of another cage and boat, as a preponderating weight; this is to be filled out of the water reserved in a cistern that is drawn out of the sliding lock-carriage.

Mr. *Robert Fulton* (see his "Observations," p. 94. and plates 9 and 10.), particularly describes a species of Cranes, by which boats are intended to be drawn up, in an iron cage, through an upright notch or shaft, and by the motion of the jibs, are to be moved over the upper canal and lowered down to float thereon, or the reverse in descending; for this purpose a perpendicular notch or shaft for the boats, and another for a water-tub, as a counter-acting and motive force, is to be provided; a reservoir is to be formed by the side of, and about 8 feet from the bottom of the tub-shaft, into which the water discharged from the tub, when at top, can be conveyed by a proper valve and spout; provision is to be made, by valves and spouts, for filling the tub from the upper or lower level of the canal, as occasion may require; and a valve is to be provided, opening by a pin in its bottom, for discharging the water when it rests on the bottom of the tub-shaft; over the tub-shaft a drum is to be fixed, for the tub-chains and crane-chains to wind round, and to this drum a fly or fanner is to connect by toothed wheels and axles, to regulate the velocity of the motion. The crane-chains are to be double, and proceed to two separate jibs fixed on centres, at proper distances from each other, having the ends of their jibs connected by a coupling-rod of the same length, by which they will always move parallel, and suit the distance of the hooks on the top of the iron boat-cage. For raising a boat out of the upper canal, the same being floated on to the cage suspended from the cranes or jibs, and the water-tub (to which balance-chains are to be adapted) being near the bottom, water is to be drawn, by a valve and spout, out of the reservoir into the tub, till it preponderates and draws the cage and boat out of the upper pound; the jib is then to be moved over the boat-shaft, and the water emptied from the tub by suffering it to descend a little farther and strike the bottom, when the boat will be lowered easily, by means of the fly, to the lower canal, where it can be floated out of the cage; and the reverse on ascending. If water is very scarce in the upper canal, and a sough or tunnel can readily be driven, for emptying the tub-shaft, the same may be made deep enough to draw water from the lower instead of the upper canal, for the preponderating power. We have not heard that any of these perpendicular lifts for boats have been executed, we shall therefore proceed to the other kinds of cranes and perpendicular lifts for the cargoes of boats.

Mr. *Bridge*, of Tewksbury, about the year 1759, contrived, for the navigation on *Stroudwater* river, a kind of cranes, with double jibs, that could be either used singly or together, and act as a balance to each other; these were erected on a strong walled bank, that separated the upper and lower levels of the river at the several mills. The boats to be used on each different level, or mill-stream and dam, were all of one size, and made exactly to suit and contain a certain number of strong wooden boxes, without any lost space. The goods or lading of the boats were placed in these boxes, and when they arrived at the first crane, one end of the chain thereof was hooked to a box, while the other was hooked to a similar box of goods in the other level, and by a peculiar structure of the crane, worked by two men at windlasses, both boxes were drawn up and suspended, somewhat higher than the bank of the upper canal, when the jibs were turned half round, and the boxes of goods were lowered down and replaced each other in the boats; the same operation was repeated with each of the remaining boxes, when each boat was ready to proceed with its new lading upon its own level to the next cranes. It can hardly be necessary to add, that the expence and delay of this method caused it to be soon laid aside.

Mr. *Edmund Leach*, in his treatise before quoted, proposes boats to be unladen and laden with boxes of goods as above, but to work the cranes by water-wheels, or by wheels for men to walk in.

The *duke of Bridgewater*'s tunnel from his canal into the coal-works at Worsley, after it had proceeded for a great way straight into the hill, came at a great depth to be under a small brook or constant stream of water, by the side of which a large water-shaft was sunk, and a drum and large brake-wheel erected over it, of sufficient size that a man who stands before the lever thereof has his two hands at liberty to pull the lines which connect with the valves, and give signals to those below, while by lunging, or stepping forwards, with his breast against the lever, he can in an instant stop the machinery in any part of its motion, or regulate the same at pleasure. There are two water tubs, which are very large and have a valve and pin to empty themselves quickly when they arrive at the bottom; they are suspended by large ropes

or cables from the drum, while other large ropes defcend therefrom through another, or coal-fhaft, by the fide of the middle or principal tunnel, into and over the navigable tunnel, which there is at, we believe, 60 yards lower level. On this loweft canal boats are ufed, fimilar in their dimenfions to thofe above, and containing boxes, which being filled with coals at the feveral terminations of this canal, in the feams of coals; the boats are pufhed along by means of rings that are fixed all along the roof of the tunnel, at the proper height for a man, who walks on the top of the coals, to lay hold of, and fhove the boat along by. The boat being arrived under the coal-fhaft, and one of the water-tubs being at the top of its fhaft, the coal-rope anfwering thereto is hooked on to the box of coals, and the defcent of the water-tub, immediately on the ringing of a bell, draws up the fame to the level of the principal canal, where being drawn afide over an empty boat, it is lowered into the fame by a flight reverfion of the motion of the machine; when the interval of emptying the tub at the bottom by its valve, gives time for hooking another box to the other rope which is at the bottom, when the other water tub is filled, and the machine fuffered to move, by the man who leans againft the brake. This very complete and economic machine was contrived and erected by Mr. *James Brindley*, and it is fo conftructed, that when coals are not drawing, the alternate defcent of the water-tubs work fome very large pumps, which are fufficient to lift all the mine-water of the lower level into the middle canal and keep the lower canal always at the proper height for navigation.

The fame tunnel of *Bridgewater*'s canal being continued a great way further into Worfley hill, till under Walkden moor, another fubterraneous canal or tunnel there begins, at 35½ yards higher level, this laft being near 60 yards from the furface; from the furface two fhafts were funk, one terminating in and over the upper tunnel or canal, and the other in and over the middle or principal canal; there is another canal ftill lower, which we have been laft fpeaking of, after paffing clofe by the canal above: between thefe fhafts a large drum was erected on the furface, with a brake wheel and a pair of ftrong ropes. Two boats being arrived at the fhafts on the upper canal, one of them loaded with boxes of lime-ftone, that was wanted at the furface, and another with boxes of coals intended to be transferred into an empty boat in the middle canal; the ends of the two ropes were faftened to a box of coals and a box of lime-ftone, when the fuperior fize and weight of the coal-boxes drew the lime-ftone to the furface, to be there landed and depofited, at the fame time that the box of coals was depofited in the lower boat, ready to proceed on the canal to Manchefter or other places. This method was in 1797 fuperfeded by an inclined-plane for letting down the boats laden with coals, from the higher to the middle level, and returning the empty boats and boxes, as we have before-mentioned. At Brierly-hill, near Coalbrook-dale, the extremity of a branch of the *Shropfhire* canal, great quantities of coal and iron in crates made of iron were let down one of two fhafts, which connected with the termination of the canal above and the ends of a rail-way in a tunnel below, from which lime-ftone in fimilar crates was drawn up the other fhaft to be placed in the boat; a large barrel and brake-wheel were fixed between the tops of the fhafts, and cranes with jibs, by which the crates could be raifed and moved from the boat over the fhaft, or the reverfe; thefe fhafts, which were 120 feet deep, were not found to anfwer, in point of expence, fo well as inclined planes, and Mr. *Telford* informs us (*Plymley's Report*, p. 296 and 307.) that inclined planes have been fubftituted, on which crates of coal, or iron pigs, or goods, defcend and draw up other crates containing lime-ftone, for the ufe of the iron-works above, by means of ropes, a drum, and brake-wheel, with a much lefs portion of manual labour, and more expedition, than was done by the fhafts above-mentioned. Near Lillifhall lime-works, on *Donnington Wood* canal, fimilar fhafts were once ufed, but are now fuperfeded by an inclined plane. At Coombe-hay, on the *Somerfetfhire Coal* canal, after the trial of Mr. *Weldon's* diving caiffon, inclined planes for defcending boxes of coals were erected, and ufed for fome years; but the delay and expence were found fo great, that the company effected the purchafe of fome mills, and under a new act of parliament, erected 22 locks in place of thefe inclined planes. Having finifhed with the different kinds of inclined planes, and other ways of procuring the afcent of boats or their cargoes, we proceed to thofe which are ufed for overcoming the principal or fudden afcents on rail-ways or tram-roads; whereon waggons or trams are ufed for the conveyance of goods, the fame being drawn on the level parts or eafy afcents or defcents by a horfe, as we fhall defcribe fhortly.

Mr. *John Buddle*, in the *General Magazine* for 1764, page 285, has given a view and defcription of the coal-waggon which had been then long in ufe on the wooden railways in the neighbourhood of Newcaftle upon Tyne. This waggon moved on four wheels of caft-iron, or of wood with iron rims, having an edge ftanding up on the rim of each wheel, in order to guide and keep them upon the wooden rails. The waggon is in fhape of an inverted prifmoid, having a door or falfe bottom hung with hinges and faftened by a hafp, that can be let go to let out the coals when the waggon has arrived on the ftaith, and over the fpout which is to convey the coals into the fhips or keels, or into a heap below as a ftore; obliquely over one of the hind wheels a ftrong crooked lever of wood is fixed and fufpended, by a ftrap when not in action; this lever, called a convoy, is intended to act as a brake, by being let down upon the wheel when the waggon is defcending down an inclined-plane, or fteep part of the rail-way called a run; and on thefe occafions the horfe is unharneffed from the front of the waggon and tied behind, and the waggon-man mounts aftride on the hinder end of the convoy, the fore-end being confined clofely in a ftaple in the fide of a waggon; and, by means of a reft that there is for his feet at the tail of the waggon, he applies juft fo much of his weight upon the convoy as will either ftop the waggon or give it the proper velocity in every part of its defcent down the hill or run: fee the *Agricultural Magazine*, vol. iii. p. 241. In the year 1783, we remember feeing an inclined plane or waggon-way as above defcribed, on which the coal waggons defcended down the hill from Wibfey-flack to the town of Bradford, which is on a branch of the *Leeds and Liverpool* canal, their velocity being regulated by convoys as above. But fome waggons which we have feen, had the convoy fixed to a moveable joint at the front of the waggon, and had a large block of wood thereon, which, when the convoy was let down, wedged in between the fore and hind wheels, and acted moft fecurely as a brake for ftopping or regulating the velocity of defcent. The empty waggons were drawn up the hill again to the coal-pits by a horfe.

An *inclined plane for waggons*, was erected fome years ago by Mr. *Barnes*, a coal viewer at Bywell, near the *Tyne* river, of which a defcription is given in the *Agricultural Magazine*, vol. iii. p. 367, as follows: "It is a very ingenious, yet fimple combination of machinery, for the purpofe of regulating the conveyance of waggons laden with coals down an inclined plane, and for bringing the empty ones back again, by the fame power that refifted its impetus in the defcent. The length of the rail-way in which the wag-

gons run is about 864 yards, which distance it descends in two minutes and an half, and re-ascends in the same space of time; so that the loaded waggon can be let down with ease and safety, the coal discharged and the empty waggon returned to the pit within the compass of seven minutes. The impelling and resisting power of motion are derived from a plummet of $16\frac{1}{2}$ cwt., which the waggon in descending and ascending alternately raises and lowers to the depth of 144 yards. The rope, by which the waggon is impelled and accelerated, winds round the axis of a large wheel in a nich or groove in the middle, which gives the rope only space to coil round upon itself, and thereby guards against all possibility of entanglement. Near to the axis of the large coiling-wheel, there is an oblique indention (a range of teeth or cogs) of cast-iron, which corresponds with and works into a similar conformation on the rim of a smaller wheel; round which the plummet-rope is coiled or warped, and it is in consequence thereof moved round, only once in six rotations of the suspending and retracting wheel, which is the same proportion that the elevation of the plummet weight bears to the descent of the waggon; to preserve the rope from injury by dragging on the ground, rollers with iron pivots and brass sockets for it to run upon, are elevated in the middle of the rail-way, but sufficiently low to prove no obstruction to the waggons which pass over them." On shorter inclined planes than the above, horse-gins are sometimes used, for drawing loaded waggons up, and at the same time letting empty waggons down the planes.

The *constructing of Rail-ways*, or, as they are often called, tram, dram, or waggon-roads, require the application of principles so exactly similar, and they are so intimately blended with our several navigable canal and river establishments, that we have before mentioned our idea of the impropriety and difficulty of separating them by deferring the account thereof to a future place in our work: the subject of inclined planes, of which we have last been treating, has required the mention of so much relating to *rail-ways*, that we beg to proceed with and finish that part of our subject, before we resume the subject of bridges, towing-paths, fences, drains, boats, moving boats, &c. which yet remain to be mentioned. From the first opening of the coal-mines on the banks of the *Tyne* river above Newcastle, until about the year 1680, it appears, that the coals were conveyed in carts and wains, from the mouths of the several pits, to the keels or vessels, that conveyed them to the sides of the ships lying below the bridge. As this kind of fuel came to be substituted for wood in London and other cities, and towns on the south and eastern parts of the island, the consumption of Newcastle coals became so considerable, that we are told, that several coal-mines, as the Kinton, Benwell, Jesmond, &c. gave employment to 400 or 500 carts or other carriages each, for conveying the produce of those pits to the waterside: the difficulty and expence of maintaining so many horses, and cost of repairing roads for such considerable traffic, occasioned the introduction, about the period above mentioned, of waggon-roads or wooden rail-ways, on which waggons of a large size, with wheels of a particular form to suit the rails, were used, and which one horse could draw, owing to the regular and easy descent with which the rails were laid. It was not until the year 1738 that this important improvement was introduced at the White-haven collieries on the western coast, and it is truly surprising to observe how slow the introduction of them was in other parts.

Way-leaves or slips of ground were set out and hired on leases, or purchased by the different coal-owners of the several proprietors of lands, lying between their pits and the river, and this, not by the nearest route, but in such a direction as gave the most easy and regular descent. The inequalities of this slip of ground were levelled as a road, hollows were filled up, and sudden hills lowered, when sleepers or large logs of wood were laid across the same, their tops being all of a regular height; upon these, two rails, generally of beech wood, were laid parallel to each other, their ends abutting close to each other, and were firmly pegged down to the sleepers. The tops of the rails were planed smooth and round; the wheels of the waggons were low and of cast iron, or of solid wood with iron rims, which were not flat on the edge, but hollow to receive and move on the wooden rails; the inside edge of each wheel projecting near two inches, in order to confine the wheels effectually to the rails, and prevent the waggon from being drawn off the road. From all considerable works, there was a main way made for the passage of loaded coal-waggons as above; and another, or bye-way by its side, for the return of the empty waggons. When coal-mines had been worked into deeper ground, and pits or shafts were opened below Tyne-bridge, the rail-ways therefrom were conducted to the top of a stage or wooden building called a staith, on the wharf or key where the ships lay; and the coal-waggons, a description of which we have already given, were either emptied at once through the spouts into the hold of the ship, or deposited in the warehouse below in store for future ships. One indifferent horse could in general draw three tons of coals from the pits to the river side upon these wooden rail-ways; which mode of conveyance became further improved by the introduction of plates of wrought iron nailed on to the rails for the waggon-wheels to run upon. Attempts were made in different parts, to introduce cast-iron instead of wooden rails; but owing to the brittleness of the material, and the great weight of the waggons in use, they did not in general succeed.

About the year 1768, Mr. *Richard Lovell Edgeworth* contrived a remedy for the principal objection to cast iron rail-roads, in making use of two or three smaller waggons linked together, instead of one large one; a model of three of these he presented to the *Society of Arts* in the Adelphi, London, and was honoured by the premium of their gold medal. In the year 1788, the same gentleman, on some temporary wooden rail-ways for manuring of land, made several experiments, in the presence of different Mechanics, on the application of friction-rollers for diminishing the friction of waggon axles. The rail-ways hitherto constructed were private property, or for the accommodation of particular mines or works, and it was not, we believe, until about the year 1794, that Mr. *Samuel Homfray*, and others, obtained an act of parliament for constructing an iron dram-road, tram-road, or rail-way, between *Cardiff* and *Merthyr Tidvill* in South Wales, that should be free for any persons to use, with drams or trams of the specified construction, on paying certain tonnage or rates per mile to the proprietors. Soon after the year 1797, iron rail-ways began to be constructed as branches to the canals of Shropshire; and, in other parts of England, Mr. *Benjamin Outram*, an engineer, began to construct the same upon improved principles, of which Dr. *Anderson* has given an account in his *Recreations*, vol. iv. pages 199 and 473.

On the 25th of June 1799, the house of commons made a standing order for extending to all bills for making any ways or roads, commonly called rail-ways, or dram-roads, all the orders (of May 7, 1794) relating to the introduction of canal bills. One principal difficulty, the provision of water, does not here occur, unless for docks or basons, which are not unfrequently necessary, at the termination of a rail-way, at a river, or existing canal; and, as the owners of streams of water are not under dread of losing the same by the passage

of a rail-way near them, and the ſame is applicable ſo much more eaſily to the uſes of the owners and occupiers, than a canal is, leſs difficulties will attend the obtaining of general powers for making ſide or collateral branches, at any future period; and of connecting the ſame with different rivers, canals, or rail-ways, making the parties a compenſation in tolls or otherwiſe, if ſuch connection ſhall appear to draw off or leſſen the trade upon any part of their line of communication, as often happens; and ſuch ought always to be carefully inveſtigated, and liberally eſtimated by the engineer, and the company be adviſed to act accordingly.

In ſurveying a line of country for a *rail-way*, principles ſomewhat different from thoſe which apply to a canal, are to be kept in view; in the latter caſe, exact or dead levels are traced out, and the caſe of towing or dragging boats thereon is nearly the ſame in going one way as in returning the other, whether laden or not, for the aſcent or deſcent of the locks or planes are there overcome by a different power than that applied to towing upon the levels; in a railway the caſe is different, the horſe which in going one way draws a very heavy load down a ſlight deſcent, has to return again with the empty waggons, or a lighter laden, up the ſame aſcent. It will therefore be neceſſary, as a preliminary ſtep to ſetting out a rail-way, to calculate as accurately as poſſible the quantity of lading which will at the firſt or any future period be to paſs each way upon the line, or on any particular parts of it, becauſe on this will depend, in a great meaſure, the ſlope that it ought to have, and conſequently the ground which the rail-way line ought to occupy. If it ſhould appear, on an accurate calculation, that the ſame weight of lading may be expected to paſs one way as the other, or that the ſame will preponderate at ſome periods one way, and at others the other way, the rail-way muſt in this caſe be ſet out in levels or very nearly ſo, and the unavoidable aſcents and deſcents muſt be made by inclined planes, as before mentioned; on which either a greater number of horſes muſt be ſtationed to draw waggons up, and in letting down, their wheels muſt ſome of them be ſlippered; or loaded deſcending waggons muſt draw up the others; the deſcent of a weight or tub full of water in a ſhaft muſt draw up a waggon, or more than one; or, a ſteam-engine, horſe-gin, or walking-wheel, muſt be uſed as a moving power, with fly or brake regulators of the motion, as we have before mentioned. If the trade will always preponderate one way, as it generally will in the deſcent from mines to navigations, and the ground will admit of the ſame, the regular inclination of the rail-way ought to be ſuch, that a horſe can draw the uſual lading down with the ſame eaſe as it can return with the waggons when emptied, or with a partial lading, in caſe of there being a ſmall aſcending trade. If the ſlope of the ground ſhall be found greater than to ſuit the above calculation, the rail-way ought to be ſet out for as great lengths together as is practicable, with the proper ſlope, and then to ſet out an inclined plane, as before mentioned. It ought to be well conſidered, where a rail-way or a branch from the ſame appears likely to have a deſcending trade at preſent, whether, at a future period, by extending the ſame forwards to any town or manufactory, or by other change of circumſtances, the aſcending trade is likely to be materially increaſed, in proportion to the deſcending; becauſe in ſuch caſe, the line would require to be altered in its ſlope, and moved to a new place, or it muſt continue to be worked to a conſiderable diſadvantage by the horſes having to travel down the line unemployed, to fetch up a portion of the loaded waggons. It will readily be perceived, that the adoption of *the beſt line*, of which the circumſtances of the trade and nature of the ground is ſuſceptible, is a taſk requiring a degree of ſkill and patient reſearch, not at all inferior to any thing required in the ſetting out of a canal, and it can hardly be neceſſary to point out the neceſſity of employing the moſt competent engineer, and allowing him proper time and aſſiſtance, in order to get the moſt eligible line marked out. A rough ſection of the different routes which appear eligible for a rail-way made by levelling with a ſpirit level, will be very uſeful in the firſt inſtance; from which, and a view of the ground, the engineer will be able to determine nearly the place and extent of the inclined planes, or ſteeper parts of the rail-way which will be neceſſary; theſe laſt being always made as ſhort as the nature of the ground and circumſtances will admit. Theſe being ſettled, the line of the intended rail-way muſt be traced on the ground, beginning at the higheſt point, and ſtretching a chain on the ground, one end being held at the point of departure, the other muſt be turned round upon the face of the deſcent, until a point marked by this end is found, which is one link (or ſomething more or leſs, according as the ſlope is to be) lower than the upper end; the chain being now moved forwards, till the hinder end reſts on the point laſt determined, the other end is to be moved, accompanied by the levelling target, until a new point is found, one link lower than the laſt, and ſo on; by which, a line having the regular deſcent of one link in a chain, will be traced out on the ground, until the place of an intended inclined plane is reached. The ſtakes which are put in to mark the place of each ſucceſſive ſtake will, as in the caſe formerly mentioned, of ſetting out a level for a canal, be found very crooked in many places; and it will be neceſſary for the engineer to ſtake out a new line, after a moſt careful view and conſideration of the ground, as the approximate line for the centre of the rail-way; which muſt be without any ſudden bends, that would occaſion friction of the wheels againſt the ſides or ribs of the rails. Single rail-ways will generally require about four yards wide, and double ones about ſix yards wide (excluſive of the neceſſary ſpace for drains and fences), and this width will require to be levelled like a road or plane: it will therefore be proper ſo to ſet out the line, that the quantity of ſtuff which is to be lowered in one place ſhall always, with the leaſt diſtance of throwing or barrowing, make up other places which are too low. Where ſudden valleys are to be croſſed, it will be neceſſary to conduct the line, ſo as to cut into the hill at each ſide of it, to find the ſtuff as readily as poſſible for forming the embankment: it will alſo be neceſſary to ſearch carefully for gravel or ſtones fit for making the road between and under the rails; and if ſuch can be got in the line, it may be a conſiderable ſaving of labour and of damage to the land, as well as a ſource of future advantage to the concern, to cut pretty deeply into ſuch materials, as we have before ſuggeſted and explained on the ſetting out of a canal; which the reader, who wiſhes to underſtand this ſubject, would do well to conſult. A line of ſtakes, exactly at a chain (100 links) apart, ſhould be put into the line laſt ſtaked out, and drove ſucceſſively into the ground, beginning with the higheſt, ſo that the head of each may be very exactly one link (that being the fall we have aſſumed) below the level of the laſt; of courſe theſe will either ſtand above the ground, or be drove in the bottom of a hole, according as the ground wants raiſing or ſinking, and will enable the engineer, on a review of the line, to judge more correctly, or to calculate where neceſſary, whether the line is ſet out in the right place to be formed at the leaſt expence of labour, and with the leaſt damage to the land; and when this is

found to be the cafe, the neceffary width of land can be determined on, and the fame furveyed and defcribed by the furveyor, for the purpofes of depofiting the neceffary plans with the clerk of the peace and with parliament. The different regular flopes or parts of the rail-way being determined in this manner, the fteeper flopes or planes that may be neceffary to join them, muft next be fet out and determined, by taking the whole fall or difference of the levels of the two ends, and dividing the fame by the number of chains that the plane is to be long, for obtaining the fall which is to be allowed between each pair of ftakes, inftead of a link as before affumed. In fetting out a fingle rail-way, it will be neceffary, at proper intervals, to allow the width of land proper for a double rail-way, for a fhort fpace, in order to form paffing-places for the waggons that are coming different ways. As part of the rail-way will in moft cafes be conducted along the fide of a hill, or on fidelying ground, it will be neceffary to confider the fame in calculating to difpofe of the ftuff, and for the neceffary ditches and drains for intercepting the fprings and furface water in every inftance, fo that the ground of the rail-way may at all times remain dry. The draining, fencing, and bridges, will require to be done on the principles which we fhall further on explain refpecting canals; and the embankments, culverts, or tunnels, which may be neceffary for preferving the proper flope in all places, are alfo to be done on fimilar principles to thofe of canals before treated of. It may be proper here to mention, that Mr. *Robert Fulton*, in his *Treatife* before quoted, pages 82, &c. has fuggefted and defcribed different kinds of caft iron bridges for paffing railways over valleys, either level acrofs, down one flope, and up the other of the valley, or rifing obliquely up; in the firft and laft of which he propofes to avoid any folid platform or top for carrying the horfe path, and to tow or drag the waggons over this open rail-way, by an endlefs rope or chain, paffing over a pulley at each end, which can be fet in motion by a windlafs, a defcending weight, or other power. On the approach to a river or yard, where confiderable quantities of coals or other minerals are to be difcharged, it will be proper to keep the rail-way upon a high level, by embankment, or on arches, or on a ftage of timber, that the waggons may be difcharged from the top of a ftaith or ftage into fhips or boats, or into carts and waggons, without being moved by manual labour. Rivers, brooks, or hollow roads, muft be croffed on bridges whofe tops are formed to the regular flope of the plane; and where roads crofs the intended rail-way, they muft either be raifed fo as to be carried over, or funk fo as to pafs under the fame; or be made up to the fame height; and the rails muft, in that part, have ribs of lefs height and greater ftrength, and the whole muft be fo firmly embedded on mafonry, that the heavieft carriages, in croffing, cannot damage it: an inftance of which may be feen in Wandfworth town ftreet, and at feveral other places on the *Surry iron rail way*.

A confiderable facility is occafioned in the *conftructing of Rail-ways*, after the plan of the whole is fettled, the act paffed, the land purchafed, the work fet out, and the ground levelled and properly fettled, by being able to begin in any part where ftone, gravel, and other materials that are wanted are to be moft conveniently had, and to work from thofe places without the heavy expence of common cartage, except for the iron rails or blocks of ftone for fleepers, if fuch are not found upon the line.

We will therefore fuppofe the work to begin at fome point where the line interfects a rubble rock or a bed of good gravel, and the furface of the road is to be covered therewith for about a foot thick, and the fame is to be nicely levelled, and any great or rough and out fized ftones fhould be carefully picked or raked off, that the whole may the fooner fettle down and become one compact mafs; thefe large ftones may be thrown forward upon the unformed part of the road, to be covered with fmaller and better gravel. This covering of rubble or gravel muft be nicely raked and levelled and beat or rammed down, to make it as compact and folid as poffible. A great quantity of blocks of hard and durable ftone muft be got in readinefs, from 8 to 12 inches thick, and weighing 150 to 200 lb. each; the fhape of them is not very material, fo that the bottom is flat, to bed firmly and evenly on the gravel, and the top is to be chifelled to a level to receive the ends of the iron rails; in the centre of this flat part a hole muft be drilled about $1\frac{1}{2}$ inch diameter, and 6 inches deep. Two flat and ftraight gauges of iron muft be provided with pins riveted into their ends to fuit the holes in the ftones; the pins on thefe gauges fhould be at the exact diftance on one of them to fuit the length of the iron, generally three feet, and the other to fuit the diftance of the rails apart or breadth of the road, ufually about 4 feet. One of the ftones being laid in the proper place for the beginning of one fide of the rail-way, and nicely bedded and rammed down upon the gravel, another ftone is to be laid at 4 feet diftance for the other fide of the road, and for bringing them to the exact diftance and level, the pins of the breadth-gauge are to be entered into the holes in each ftone, and a common or mafon's level is to be applied to the top of the gauge; if the ftone laft laid is found too high or two low, it muft be lifted up again, and gravel muft be raked out, or more fine and good gravel fprinkled in and rammed down, until the right height is obtained; the ftone is then to be laid on again, and brought to its proper place by means of the gauge and level; care is to be taken that the top of the ftone is level, fo that the flat ends of the guage bed exactly and evenly on the ftone all around the hole; and if this is not the cafe the chifel muft be ufed to take down any irregularity and produce this bedding of the gauge bar. A third ftone is then to be laid on one fide and the length-gauge pins entered into the holes, by which the exact and proper diftance of the ftones will be afcertained, and for trying the truth of this ftone as to height, a level is to be ufed, in which a line is very carefully drawn by the engineer, making the exact angle with the perpendicular line that the rail-way is to make with the horizon; this being applied upon the length-gauge will fhew whether the ftone laft laid requires more gravel under it, or any to be taken out, obferving always to level the gravel carefully and to ram it down, and alfo to ram the ftone down upon the gravel, before each ultimate trial of its proper pofition as to level, its diftance meafured by the gauge from the other ftone, and its range by a line ftretched in direction of the intended rail-way. With thefe precautions the ftones are to be fucceffively laid, and gravel of the beft quality, and without any large ftones, is to be laid in, to fill up the fpaces between them; and fome on the outfide of the ftones, the better to fecure them in their places; and when a certain length is done, as no mortar or other foft material is ufed which requires time to dry or fet, the work is ready to receive the rails, and will be then immediately fit for ufe, to carry forward the gravel, ftones, and other materials for the work as it proceeds. We have before mentioned that the ground work fhould be fettled; and for this purpofe the levelling of the road fhould be performed early in the winter, and the rains and froft will effectually fettle it, by the time the work gets dry enough in the enfuing fpring;

before which, the work ſhould be carefully gone over again, to level and fill up any parts which have ſettled more than was expected and allowed for.

The *caſt Iron Rails*, in the earlier uſe of them, as on the extenſion of the Caldon branch of the *Trent and Merſey* canal, to Mr. *Gilbert's* lime-works, 4 miles in length, (which was in uſe long before 1794,) were faſtened down upon longitudinal rails of wood, which lay acroſs ſeveral wooden ſleepers, embedded in the gravel, as we have deſcribed above; theſe rails were three feet long, and had two holes, at 18 inches apart, to receive the wooden pins which faſtened them down, or rather confined them in their places, on the wooden rails: (ſee *fig.* 31, *Canals, plate* iv.) at one end there was a triangular projection, and at the other a ſimilar notch which fitted into each other; a rib ſtood up along one ſide, to confine the waggon wheels to the track; and oppoſite the holes, the rail which was about $1\frac{3}{4}$ inch thick and weighed about 42 lb. was made wider to ſtrengthen that part; yet, with this precaution, ſuch rails were very liable to break in two at the pin holes, as well as to looſe their connecting triangular piece; the rib alſo was very liable, by the wheels or other things ſtriking againſt it, to get broken off near the ends, and the waggons were not confined from running off the road in ſuch places. The rails of the *Surrey Rail-way* are repreſented in *figs.* 32 and 33, and are, we believe, of the moſt improved conſtruction; they have their ends reſting on ſeparate blocks of ſtone embedded in the gravel as above deſcribed, and, inſtead of pin-holes through them, each rail has a ſimilar rectangular notch in its end, which, when two of them are laid cloſe together, forms a counter-work-hole for a ſquare and headleſs ſpike of iron, that is to faſten the ends of both the rails. Theſe rails conſiſt of a rectangular plate of caſt iron, 3 feet 2 inches long, 5 inches broad, and 1 thick; a piece of metal about half an inch thick is added in the caſting, to increaſe the thickneſs at each end for 5 or 6 inches in length, where it is to bear on the ſtone and receive the ſpike; a rib is caſt on to each edge of the rail, one of them above, and ſerves to guide and confine the waggon wheels; the other below for adding ſtrength; theſe ribs which are about three-fourths of an inch thick form by their top the ſegment of a large circle, being about $3\frac{3}{4}$ inches high in the middle, and about $1\frac{1}{2}$ inch at the ends, by which theſe ribs are calculated to give the greateſt ſtrength to the rail in the middle, where it has no bearing, and to make them not to be eaſily ſnipped or broken off, as mentioned of thoſe rails above, whoſe ribs are of an equal height throughout; ſmall circular projections of metal are caſt on to the width of the rail near each end, and the ſame are carefully bedded upon the ſtone, for preventing the rail from being overturned laterally, by the action of the wheels againſt the rib. For croſſing of common roads, the rib, (ſee *fig.* 34,) is made only an inch high throughout, and near an inch thick, and its edges are well rounded off. In theſe ſituations, a few rows of pavement, of good ſquare ſtones, ſuch as the carriage way of the ſtreets of London are now paved with, are kept nearly or quite as high as the ribs of the rails, by which the heavieſt waggons, carts, and coaches paſs over them almoſt without any ſenſible jolt. Croſſing-rails are uſed at every paſſing-place, or point where waggons are to paſs out of one track of rails into another, which are very numerous in the company's yard, by the ſide of their baſon or dock for barges, in order that empty waggons or thoſe loaded may be readily puſhed into one of the tracks further off the wharf, to let other full or empty ones advance, on their proper track, to the ſides of the barges. A B C D, *fig.* 35, repreſents one kind of croſſing-rails, ſhewn in connection with four common rails, parts of which are repreſented by E, F, G and H; a wedge or tongue of wrought iron, I, is moveable round a pin, and is repreſented in the figure, as placed againſt the ſtub K, ſo that the track from G to F is clear for one of the wheels of a waggon; and by moving the wedge I till it reſts againſt the ſtub L, the track from H to E would be clear; before the waggon can paſs in the directions above-mentioned, the wedge will often want moving by hand to the proper poſition, but in going in the oppoſite direction from E to H, or from F to G, the action of the wheel againſt the wedge will always move it into the right poſition; there is a circular guard or ſtub caſt on to the rail behind the joint of the wedge for preventing the wheels from ſtriking directly againſt the end of the wedge.

The method in which the rails are faſtened to the blocks of ſtone on which they reſt, is by an octagonal peg or trunnion of good ſound dry oak, fitted to the hole in the ſtone, ſo as to drive eaſily into the ſame, otherwiſe its ſwelling by wet and the driving of the ſpike might ſplit the ſtone, this plug of wood is not long enough to reach the bottom of the hole, and is ſawed off even with the top of the hole; a hole is then bored through this plug of wood, and an iron ſpike with a flat point, and a head juſt fitted to the counter-ſunk notch in the ends of two rails, when applied endways together, is drove; by which the rails are ſufficiently confined, and yet in caſe of any wear or ſettling of the ſtone, ſo that the rail gets a little looſe, it is capable of moving that ſmall ſpace without breaking out the ſides of the pin-hole in the rails. It will be proper, always to drill a ſmall hole from the bottom of the plug-hole, quite through the ſtone, for the rain water to ſoak away into the gravel, otherwiſe the freezing of water in the holes would often burſt the ſtones. Care muſt be taken from time to time, to keep the tread or ſurface of the rails clear of dirt or ſtones, which laſt would ſtop the waggon, and perhaps break the rails; and too much pains can hardly be taken by raking and ſorting the gravel, for the finiſh or top of the road, and rolling or ramming of it down, to ſettle the ſame into a compact and hard road as ſoon as poſſible, having no looſe ſtones, which the horſes are always kicking on to the rails, and while this is the caſe, the man who attends the waggons ſhould always go before his horſe, and look carefully to the rails, and remove any ſtones that may have got upon them. The waggons in moſt general uſe on the *Surry iron Rail-way* weigh, including their loading, about $3\frac{1}{4}$ tons, the wheels are two feet five inches high, of caſt iron, with 12 ſpokes, which get wider as they approach the hub, which is eight inch long to receive a ſmall wrought iron axle; the fellies or rims of the wheels are two inches broad, and nearly as much thick, and the ſharp angles are rounded off, ſo that theſe wheels are capable of being uſed without damage on any hard common road; a very principal advantage attending the modern uſe of rail-ways. The axles of the wheels are fixed at two feet ſeven inches diſtance; the bodies of theſe waggons are ſeven feet nine inches long, four feet five inches wide, and two feet four inches high; theſe are uſed for bringing down chalk from the Surry hills to make lime, carrying back manures, &c. The founders, and others upon the line, have trucks or waggons of different kinds to ſuit the nature of their goods; the only apparent limitations being in the width of the wheels and carriage, the length of their axles, and weight of lading.

For the more ready emptying or ſhooting the contents of the waggons into barges lying in the dock, a ſtrong ſtage is erected on the wall, which projects over the water, and in

order to turn waggons ſhort round and back them on to this ſtage, the rail-way paſſes over a large circular plate of caſt iron, which is ſuſpended on a pin beneath its centre; there being a circular ring under its circumference, which moves round freely, with a conſiderable number of ſmall wheels or rollers, whoſe axles are fixed therein, (ſee *figs.* 45 and 47, *Plate* VII.) upon another circular iron plate firmly fixed below; by this arrangement, it happens, that as ſoon as the fore and hind wheels of the waggon are advanced on to this circular plate, a very ſmall force applied to the waggon will turn it a quarter round, along with the plate and rails on which it reſts: the waggon is then run backwards off the plate, on the ſtage before mentioned, and its contents are ſhot into the barge below; it is then returned upon the plate, and the ſame is turned round until the rails thereon match the track, and the waggon can then move forwards, to make way for another loaded waggon, to be emptied in like manner, or it can be ſhoved backwards to a croſſing-place, as may be required. A ton weight or more in a waggon can eaſily be ſhoved along by a man, as he does a wheel-barrow. Rail-way branches are capable of being conducted into every foundery, or other great work near the line, to terminate under their large cranes for hoiſting goods, ſo that heavy articles can be loaded at once on to trucks for the rail-way. The branches of a rail-way admit of being multiplied almoſt without limit; farmers and others who have but an occaſional trade, may have their own waggons to be kept locked, and left for them by the ſide of the rail-way, one or more at a time, from the gang that is paſſing along the line. About November 1800, Dr. *Anderſon* recommended, in his *Recreations*, vol. iv. p 204, the adoption of a double rail-way for heavy carriages between London and Bath; and about March 1802, Mr. *R. L. Edgeworth* recommended, in *Nicholſon's Journal*, 8vo. vol. i. p. 221, the experiment to be tried, on one of the great roads, for ten miles or more out of London, of a rail-way with four tracks, one for ſlow and another for faſt travelling carriages going each way, in order to avoid meeting or delay; theſe he propoſes to adapt to chaiſes and ſtage coaches, by means of low cradles or platforms, with wheels adapted to the rails, on to which a chaiſe, coach, or other carriage, could be drawn, and there confined, in order to be drawn along the rail-way; and which cradles the coaches might leave at any deſired point, to be drawn on the common road, which he propoſes to have by the ſide of his rail-ways. Dr. *Anderſon*, in the volume above quoted, recommends railways to be made from the docks in the Iſle of Dogs, to different points in the environs of London; and he propoſes the bodies of theſe rail-way waggons to be moveable, and to be hoiſted off by cranes with their lading in them, and be placed on other, and larger wheels, with ſhafts adapted to the ſtreets; which, after delivering their lading, would return, perhaps laden with other goods, to the cranes to be replaced on the rail-way wheels. In vol. v. p. 291, of the doctor's work, it is recommended to uſe waggons on the propoſed rail-way with wheels large enough, and of a proper conſtruction, to be uſed in the ſtreet alſo. Wherever any conſiderable work is to be done, as in the excavation of the *London-Docks*, it has been found to anſwer, to lay down temporary rail-ways; and ſuch as admit of being moved as parts of the works become complete. For the uſe of mines, this facility of removal is often of conſequence, as the veins or pits wear out.

Doctor *Anderſon* obſerves, that 20 tons, in a barge upon a canal, will be drawn with eaſe by one horſe, travelling at the uſual rate that waggons move; and that on a rail-way the ſame horſe would, under favourable circumſtances, tranſport the ſame quantity of goods in a given time: but Mr. *Fulton* ſays, that five tons to a horſe is the average work on rail-ways, deſcending at the rate of three miles per hour; or one ton, upwards, with the ſame ſpeed. Mr. *Telford* obſerves, that on a rail-way well conſtructed, and laid with a declivity of 55 feet in a mile, one horſe will readily take down waggons containing 12 to 15 tons, and bring back the ſame waggons with four tons in them. Mr. *Joſeph Wilkes* in 1799 ſtated, that a horſe of the value of 20l. drew down the declivity of an iron road $\frac{5}{16}$ of an inch at a yard, 21 carriages or waggons, laden with coals and timber, weighing 35 tons, overcoming the *vis inertiæ* repeatedly with eaſe. The ſame horſe, up this declivity, drew five tons with eaſe. On another part of the road, where the acclivity was $1\frac{3}{4}$ of an inch at a yard, the ſame horſe drew down three tons; but it was neceſſary to ſlipper or lock the wheels here, to prevent his being overpowered by the deſcending weight. On a different rail-way, one horſe, value 30l. drew 21 waggons of 5 cwt. each, which, with their loading of coals, amounted to 43 tons 8 cwt. down the declivity of 3 of an inch in a yard; and up the ſame place, he afterwards drew ſeven tons; the cwt. in all theſe experiments of Mr. *W.*'s being 120lb. In the ſummer of 1805 a trial was made on the *Surry* rail-way by Mr. Bankes, wherein a horſe, taken indiſcriminately out of a team, drew 16 waggons, weighing upwards of 55 tons, for more than ſix miles along a level or very ſlightly declining part of the rail-way.

Dr. *Anderſon* has calculated the expence of carrying goods in common waggons, or turnpike roads, a diſtance of eight miles, at 3s. 4d. per ton, and of carriage, the ſame diſtance, on a rail-way, at 4d. per ton, or only a tenth part of the former. *Recreations* iv. 208.

For ſteep deſcents, ſledges, or ſlippers of iron, muſt be provided, ſimilar to thoſe in common uſe with road-waggons, which can be placed under the wheels of the rail-way waggons, and hooked to the ſide of the waggon by a ſhort chain, in order to cauſe the wheel or wheels to ſlide upon the rails, whereby the tendency to deſcend may be checked.

Mr. *William Chapman* has, in his *Obſervations*, p. 42 and 54, recommended the uſe of waggons, that are to run on to the rail-ways that are to be prepared in the bottom of a flat-bottomed boat, inſtead of unloading the contents of the waggons into the boat; and when this boat with its waggons has arrived at its deſtination, the waggons are to be run out upon other rail-ways, to proceed forwards by land if neceſſary.

Mr. *Carr*, we are told, has introduced in the mines of Shropſhire, and other places, a ſlight kind of iron rail-ways, called train-roads, for the uſe of very ſmall waggons in their under-ground works.

Mr. *R. L. Edgeworth* has ſuggeſted (*Nicholſon's Journ.* 8vo. i. 223,) the uſe of light circulating chains running upon rollers, which are to be put in motion by ſmall ſteam engines placed at conſiderable diſtances; to theſe chains he propoſes carriages to be attached, for dragging them along upon rail-ways inſtead of uſing horſes. Since ſteam-engines have been brought into uſe, to work by the expanſive force of ſteam, and requiring no water for condenſation, a ſucceſsful trial of applying them to moving the trams on a tram-road has been made, *viz.* in February 1804, on the *Cardiff and Merthyr* rail-way, where 10 tons of iron (long weight) loaded on tram-waggons, with the additional weight of about 70 perſons for great part of the way, were drawn for nine miles upon the tram-road, at the rate of near five miles per hour, by the uſe of one of theſe ſteam-engines fixed on its own waggon made by Mr. Homfray, (for which engines Mr. *Trevethick* had previouſly taken out a patent, though it

is perhaps an old invention) no supply of water for the boiler being found necessary in this distance.

The cost of a single rail-way, with crossing-places, for a descending trade, was estimated by Mr. *Fulton*, who wrote in 1795, at about 1600l. per mile. Mr. *Wilkes*, in 1799, stated, that the expence of completing a mile of single rail-way, where materials of all descriptions lay convenient, and where the land lies tolerably favourable for the descent, would be about 900l. or 1000l. fenced, &c. exclusive of bridges, culverts, or any extra expence in deep cutting or high embankments. Dr. *Anderson* mentions, in 1800, the sum of 1000l. per mile as the probable cost of a double rail-way in the most favourable situations, and of very stout ones in the vicinity of London, where labour is dear, not less than 3000l. per mile; and Mr. *Wilkes* says, that wherever the quantity of goods to be conveyed on a rail-way, having a descent of not more than ½ an inch in a yard, amounts to two-thirds of downwards, and one-third of upwards loading; it is a doubt, if it will not, in that case, be a cheaper conveyance than by a canal, besides the rail-way being more certain, where dispatch is necessary, on account of frost and dry seasons. Another advantage attending rail-ways is, the greater certainty of the estimates for the same, when made with care and judgment, and the facility with which the whole work may, in general, be contracted for, to be completed at a stated time. The principal rail-ways which have been executed, are the *Cardiff and Merthyr*, the *Caermarthenshire*, the *Sirbowy*, the *Surrey*, and the *Swansey and Oystermouth*; and such branches will be found to the *Ashby de la Zouch*, *Cromford*, *Derby*, *Erewash*, *Lancaster*, *Leeds and Liverpool*, *Peak Forest*, *Shropshire*, *Somerset Coal*, *Trent and Mersey*, and several others, to which number almost every day is adding.

The *constructing of Bridges* for crossing canals and navigable rivers, often occasion a very serious part of their whole expence, and this circumstance occasioned the attempt in some of the earlier canals, to substitute paved *fords* in many instances; Mr. *James Brindley* proposed these at first, for some places on the *Trent and Mersey* canal; and on the canal which Mr. *Davis Dukart* constructed to the Tyrone collieries in Ireland, these were substituted in place of bridges. Mr *Fulton* has recommended the general adoption of fords on his small canals, but Mr. *Chapman* observes, that the water in such cases must not exceed two feet nine inches in depth, as otherwise hay, sheaves of corn, &c. in common carts would be liable to get wet in crossing. On the China canals we read, that there are elliptical arches of stone over their canals, the longer axis being vertical, and high enough for the masts of their vessels; these bridges being only intended for foot passengers, and are ascended and descended by steps. On our canals, bridges for foot passengers only are generally constructed of wood, and are mounted by steps, as at Paddington on the *Grand Junction*. In all large and important bridges the arches should undoubtedly be so formed that the materials thereof are in equilibrium, independent of the cement that may be used between the stones or bricks; the principles of which arches will be found in our articles Arch and Bridge; but for the common bridges for crossing of canals, which are wanted in such great numbers, flat semi-elliptical arches have been, in general, adopted, on account of such giving width for the canal and towing-path underneath, without raising the top any unnecessary height, which so enhances the expence of landing up, or forming the slopes to the bridge. From the habits which necessity has in a great measure introduced with canal bridge-makers, of using only the best materials, performing the work with great care, and not striking their centres too soon, such bridges are found to stand tolerably well, although very far removed from an equilibration figure; yet instances are not wanting on most canals of their settling, and even falling down in some cases. A kind of brick bridges have long since come into almost general use on canals, of which we have given a plan, section, and perspective view. See Canals, *Plate* IV. *figs*. 40, 41, and 42. The form of these bridges is well calculated for saving of materials, and giving strength at the same time, the whole of the walls being more or less battering, and the side walls are splaying outwards at their ends, to make the entrance on to the bridge the more easy, by which the side walls are rendered curving inwards in every part. In the building of bridges the utmost care must be taken to sink the foundations down to sound stuff, or to drive piles on which to begin the work; it is a good practice to have wedge like or arching bricks made, on purpose to use after a certain number of courses of key bricks, or those forming the sofits of the arch, and to introduce oblique courses of bricks for the more effectual tying of the work together, as we have mentioned in speaking of tunnels. Large bricks made of the best earth and well burnt, should also be used, placed on edge upon the top of the walls of the bridges, as a coping, unless very good stone is near at hand, the top corners of the coping bricks or stones should be carefully rounded off in the making, in order that the same may present as few angles as possible for the weather or the traffic to catch hold of.

We have before mentioned the care which ought to be taken in every instance, to find stuff with the least possible expence of moving it, for landing up the bridges; from these having, in some instances, been left too steep for the convenient and safe use of the public; it has not been uncommon, in later acts, to make provisions on these subjects; on the *Grand Western* it is enacted, that the ascents to the bridges shall not exceed 2½ inches in a yard, and on the *Wilts and Berks* this rise is limited to 3 inches in the yard at the most. The width of the carriage-way, on the bridge, in the narrowest places, is also fixed in some acts, wherein we have seen 12 feet mentioned as a limit in some cases. We have before observed, that the canal ought, if practicable, to be conducted into deepish cutting, wherever a brick or stone bridge is to be erected, in order that the stuff may be thereby procured, for landing up each side of the bridge, and that the abutments of the bridge may be the more solid, and the foundations more likely to reach sound stuff, without an extra depth of walling, or the necessity of piling for such purpose. On this account it is, that the tail of a lock generally presents a proper place for a bridge, and where the walling, which must have been made for wing-walls, below the lower lock-gates, is avoided, or turned to account in the bridge. In places, where from the great traffic that is to be expected, or other cause, a towing-path will be wanted on both sides of the canal, the bridges should be made on a scale large enough to admit of a towing-path on both sides under the bridge, as in the two or three bridges nearest to Paddington bason, on the *Grand Junction*.

For *occupation*, or accommodation bridges, and even on some public roads, as on the *Sankey* canal, and others, a kind of swing or swivel bridge has in general been adopted, of which some mention has been made under our article Bridge. See *fig*. 43 *Canals*, *Plate* VII. A flat platform of wood strongly framed together, covered with planks, and having side rails, is prepared, wide enough for the purposes of a bridge, and about half as long again as the canal is wide, in the contracted walled part intended for the swing bridge. One end of the platform for this bridge is framed as light as can be consistent with strength, and the other very heavy, with provision for stowing large

ſtones or pigs of caſt iron therein, ſo that the ſame will reſt in equilibrio on a point at about one-fifth of its length from the heavy end; under this point, a large circular plate or ring of caſt iron is fixed, having a ſmooth circular hollow ſunk therein. An exactly ſimilar plate is embedded, and firmly fixed on the ſolid wall at the ſide of the canal, except that this laſt has a ſtrong iron centre or point ſtanding up, to enter a hole ſunk in the upper plate to receive it. On this pin the bridge is ſuſpended in equilibrio, and in order that no impediment may ariſe to turning the bridge round, when its balance is by any circumſtance deſtroyed, a number of ſmooth caſt iron balls, of two and a half or three inches diameter, are placed in the circular groove or hollow ring in the two plates, which act effectually as rollers for leſſening the friction between the circular plates, in turning the bridge on and off the canal; or, a ring containing ſeveral rollers (*fig.* 45 and 47), is ſubſtituted inſtead of the iron balls above-mentioned, between the lower and upper plates *figs.* 44 and 46. A receſs is formed on the bank juſt to receive the bridge, when a boat is to paſs, and when the bridge is turned acroſs the canal, each end of the bridge (which ends are rounded into circular arcs, ſtruck from the centre pin), ſlides on to a ſimilar circular receſs in the road, with a firm bearing at a very ſmall diſtance below the ends of the bridge, when it is in equilibrium, on the centre pin and balls or rollers; by this arrangement it happens, that the heavieſt loaded carriage croſſing the bridge, is not able to depreſs either end of the bridge on which it paſſes, in any ſenſible degree. The engineer ſhould carefully avoid the uſe of theſe ſwing, or indeed of any moveable bridge, where the towing-path is to change from one ſide of the canal to the other, becauſe the bridge muſt remain acroſs the canal until a barge in paſſing, is got near enough for the towing-horſe to croſs over the bridge, and the bridge muſt then be turned off the canal before the boat can paſs, and it continually happens, unleſs the towing-line is of great length, or is caſt off at ſome diſtance before the boat arrives at the bridge, or the greateſt dexterity is uſed, that the boat ſtrikes the bridge before it can be turned off the canal into its receſs: where ſeveral boats are cloſely following each other, there difficulties are much increaſed, and great delay muſt take place, or the bridge will ſoon be knocked to pieces. Swivel or turn bridges have ſometimes been erected on the towing-path ſide, but they form there a moſt ſerious obſtacle to the towing of boats; and on that account are generally placed on the off bank, and as no methods have hitherto been brought into general uſe, of turning on or ſhutting ſuch bridges for perſons to paſs over them, except the perſons, or ſome others, are at the time, on the ſame bank of the canal on which the bridge ſtands, in order to turn it over the canal; this has occaſioned the neceſſity of clauſes in every act, or ſet of bye-laws, requiring boat-men always to ſhut to every ſwing-bridge, or draw-bridge, as ſoon as their boat has paſſed. The great loſs of time and labour in thus continually turning the bridges on and off, the wear that ſuch continual uſe occaſions, and the frequent damage which ſuch bridges ſuſtain from boats ſtriking againſt them, if, by the leaſt delay of the boat-men or accident, they are not turned off before the boat gets up; have occaſioned our thinking a good deal on the ſubject, in hopes of deviſing ſome method of turning the bridge on when wanted, from either ſide of the canal; becauſe ſuch a contrivance would authoriſe the alteration of the preſent regulations, and require each ſwing-bridge to be left open, and out of the way of the navigation, except during the time that it was actually in uſe, by perſons or carriages paſſing over it: another material evil would thereby alſo be remedied, that is, the difficulty which now exiſts of preventing the farmers' cattle, in the fields on the off ſide of the canal, from paſſing over the bridges, and eſcaping along the towing-path, without an expenſive circle of fencing and a gate to ſeparate the bridges from the fields, for no gate or obſtacle can conveniently be made on the towing-path ſide to obſtruct their paſſage. Chains and pulleys under the canal, and motion conveyed upon *Bramah's* patent principle, in pipes under the ſame, were conſidered among others, as the means of turning the bridge on, when wanted; but, our ſpeculations hereon were, happily, at the moment of writing this (October 1805,) interrupted by the information of a method, which was ſucceſsfully brought into practice very lately, by Mr. *Benjamin Bevan*, the engineer upon the middle diſtrict of the *Grand Junction* canal, *viz.* near the ſteam-engine on the Wendover branch, where a ſwing-bridge of the common conſtruction, with a railing or fence on each ſide of it, has an addition made to it, on the ſide that is next the canal when the bridge is open, or in its receſs, at about three-fourths of its length, from the centre pin on which the whole turns; this conſiſts of a jib like that of a crane, or the bars that are ſometimes uſed for ſtopping carriages at the ends of ſtreets: an upright piece of wood is hung by two hooks and thimbles, like thoſe of a common gate, to the ſtandard or upright on the ſide of the bridge; to the top of this a rail of 4 or 5 feet long is fixed horizontally, ſupported by a brace underneath, from near the bottom of the upright piece; on the top of the horizontal piece are two ſtrong ſtaples fixed, adapted to receive the thickeſt end of a very ſlender and light pole, ſuch as are uſed for the handles of hay-rakes, but they muſt be longer, and rather larger for wide canals; a nail drove in between the ſtaples through the pole fixes the ſame, and makes it form a light and eaſily renewable continuation of the top rail quite acroſs the canal, ſo that a perſon, wanting to croſs the bridge from the towing-path, can take hold of the end of the pole and pull by the ſame, and thereby turn the bridge over the canal; or, if a perſon has croſſed the bridge towards the towing-path, he can with equal facility take hold of the end of the pole and ſhove the bridge round to the other ſide. The hinges of the jib that carry the pole are ſo adapted, that the pole has a tendency to hang directly acroſs the canal, to the moſt convenient point for being taken hold of; but, at the ſame time it is with the leaſt force turned round on its hinges until it is brought along-ſide of the bridge, and quite out of the way of boats that are paſſing. This very ſimple and cheap apparatus, we are told, anſwers effectually; no impediment is offered to the horſe or towing-line; but when a boat arrives, whatever part thereof ſtrikes againſt the pole, it recedes and ſuffers the boat to paſs, and then by its own weight reſumes its ſituation acroſs the canal, ready for turning the bridge. The ſolid part of the jib is not made long enough to be liable to be ſtruck by the boat, or a man ſtanding thereon; and poles in plenty, of the proper ſize and length, can be in readineſs, for replacing in a minute any pole which is worn out or broken by accident.

Bridges which have no towing path under them, preſent a great obſtacle to towing, becauſe the line muſt in thoſe caſes be caſt off from the barge; except, occupation bridges, like the wooden one at Rotterdam in Holland, could be introduced, where the bridge, we are told, conſiſts of two ſeparate ſegments, each ſupported firmly on its own bank, and leaving a ſlit quite acroſs the bridge for the towing-maſt to paſs through, and thus they avoid caſting off of the line: this ſlit need not be ſo wide but that foot paſſengers can with eaſe and ſafety ſtep acroſs it; and, on the paſſage of horſes or carriages, a moveable flap turning quite flat back upon hinges, might be turned over to complete the road.

Where swivel bridges of great width and strength are required, and need but seldom to be turned off, as for admitting ships at high water to the *West India* and *London Docks*, double wooden or cast iron swivel bridges are in use, with a moveable frame under each part, constituting parts of the ribs of the bridge, which frames turn on a hinge or joint, and are taken up or suspended by a screw at the other end, to clear the walls of the bridge when the same is to be turned off; and which, when the bridges are turned over to meet in the middle, can be let down by turning a winch, so as to fall in strong grooves prepared in the copings of the walls, and complete the abutments of the ribs of the bridge, as strongly almost as a fixed wooden or iron bridge could be made; an excellent example of which may be seen in Wapping street, crossing the entrance to the *London Docks*, as mentioned under the article Bridge. It appears that Mr. *H. Shadwell* was rewarded for some improvements to swivel-bridges which he suggested to the *Society of Arts*. See their *Transactions*, vol. xiii. page 227.

Draw-Bridges are not uncommon as accommodation bridges on some canals: the frame or platform of them, with their side rails attached, is moveable on strong hinges upon the top of the wall or one side of the canal, and when down shuts into a groove prepared on the opposite wall, so as to present no projection or obstacle to the road over it. For raising these bridges, two strong and tall posts are fixed upright on the bank of the canal a little behind the hinges of the bridge; on the top of these posts are two very long and tapering pieces of timber called balance-beams, which turn on a hinge near their middle, their small ends being connected by chains to the further end of the bridge, to which the thick ends of the balance beams are made to be a counterpoise, by means of lead or iron nailed on to the same if necessary: when the bridge is shut, or prepared for passing over, the balance-beams rest nearly horizontal, there being a chain attached to the thick end of each, which hang down and can be reached by a man or boy, and by pulling at which, he can rear the bridge up upon its hinges for boats or vessels to pass. For crossing the Docks in Liverpool in different places, very large draw-bridges are in use, supposed to be the largest in England. But we are informed by Mr. Rennie, an engineer of the first eminence, that he has seen much larger draw-bridges in France. On the *Forth and Clyde* canal the draw-bridges are double, meeting in the middle of the canal when shut down. It appears that the Chinese have a sort of draw, or rather sliding bridges over the piers of the flood-gates of their canals, which, to prevent interruption to the masts of vessels, are constructed so as to be easily withdrawn when vessels are about to pass; they are flat wooden bridges, narrow and light, resting on rollers fixed in their frame, and running on a couple of loose spars that are withdrawn after the bridge. Wooden bridges are very often wanted for carrying the towing-path over the entrances to docks, or the side branches of a canal, and from their great span, to avoid a narrow place at the turning; these are often attended with considerable expence; they should be constructed of very sound and durable timber, well trussed, and as light as is consistent with strength, as they are seldom made wide enough to be used except by men and horses. We cannot too often advise that bridges of wood or iron, and stone ones also of large span, should be wider at the abutments, and diminish by a proper curvature of the sides to the middle, to prevent the strain of the materials on a sudden lateral impulse, from causing them to give way and cripple sideways.

The ingenuity and enterprise of British artists have given rise within the last 30 years to an improvement of the first importance to river navigation, by the introduction of *cast iron bridges* of great span and height, by the adoption of which, in favourable situations, ships may be admitted further up into our large rivers; and in almost every case, the impediments to navigation may be removed that are occasioned by the narrowness and lowness of the arches of our old stone bridges, which not only exclude or interrupt the towing-path and necessitate barges to lower their masts, but in general cause such a fall in the water, owing to the deficiency of their water-way, as to be dangerous and impassable at particular states of the river. Near Coalbrook-dale on the *Severn* river this improvement was first carried into effect, as particularly described in our article Bridge. A perfect model of this bridge, which is 100½ feet span and 45 high within the arch, was prepared by Mr. *Abraham Darby*, who cast the same, and presented to the *Society of Arts*, in whose collection it may be seen by any one who applies in the Adelphi: see their *Transactions*, vol. vi. pages 228 and 232. Buildwas bridge of iron over the *Severn*, within two miles of the former, we have already described in the article referred to, and have only to add, that Mr. *Thomas Telford*, the engineer of this bridge, has given a plate of the same in *Plymley's Agricultural Report of Shropshire*, page 316. For the principles on which the Wearmouth bridge, which we have described, is formed, Mr. *Rowland Burdon* on the 18th September 1795 took out a patent, which see in the *Repertory*, vol. v. page 361, where a view of this very curious structure will also be found. We are sorry to add that we heard lately in conversation, that this bridge has shewn symptoms of twisting or giving way side-ways, which have greatly alarmed some persons for its safety. The cast iron bridges at Bridgewater on the *Parret* river, and at Staines on the *Thames*, have been mentioned in our article referred to above; the latter, owing to the mistaken economy of the trustees, in having vaults made in the abutments, which ought to have been of solid masonry, gave way, and has been entirely taken down, as the new stone bridge erected before it, was obliged to be from the same cause. We cannot enough admire the prudent precautions of the select committee of the House of Commons in 1800, who investigated the different proposals for rebuilding of London bridge. (See *Tilloch's Philosophical Mag.* vol. x. page 13.) They consulted the opinions of the most eminent professional men, and had a very accurate set of models, constructed in brass by Mr. *Berge*, the successor to the celebrated *Ramsden*, under the direction of Mr. *Atwood*, for illustrating the nature and properties of equilibrium arches. One of the designs which were presented to this committee, and which has since been engraved by Mr. *Wilson Lowry* and published, is that of Messrs. *Telford and Douglas*, for a single arch of cast iron of 600 feet span, and rising 65 feet above high-water mark: as this scheme has not yet, nor ever may be carried into execution, it would be swelling the present article too much to detail the excellent provisions which the contrivers had made, for the execution and stability of this grand work. We proceed, therefore, to mention, that Mr. *Fulton*, in his treatise so often before quoted, has given designs (plates 14, 15, and 16), and explained the principles, page 120, of different bridges of cast iron. On the 24th May 1796, Mr. *James Jordan* took out a patent for constructing bridges which should be suspended from ribs of iron above: see *Repertory*, vol. vi. page 220, and on the 7th February 1797, Mr. *John Nash* obtained a patent for a method of constructing bridges of hollow quoins of iron, that can be filled with masonry or other solid matters after the bridge is put together; the piers of bridges he proposes in like manner to con-

ſtruct of hollow caſes of iron, to be filled with maſonry after they are brought to their proper places: ſee *Repertory*, vol. vi. page 361. Of wooden bridges for large and navigable rivers, we have given an example in the once juſtly famous Schaffhauſen bridge over the *Rhine*, in our article BRIDGE. Mr. *Fulton* mentions a very famous one at *Wettingen* in Switzerland; and has given us deſigns for bridges for newly ſettled and woody countries, wherein large timbers dowelled together, ſupply the place of key-ſtone, above which the platform for the road is to be ſupported. The ſame gentleman has propoſed in conſtructing the above kind, or iron bridges that are very flat and low, to obtain the neceſſary ſtability of the butments, by continuing the line of key-timbers or ribs with their proper curvature for ſome diſtance into the bank on each ſide. We have before ſpoken, under the article BRIDGE, of the proper form of the projecting angles of the piers of a bridge, and ſhewn that for navigable rivers, ſharp corners ſhould be avoided, from the damage that ſuch might do to the boats and veſſels.

Bridges will be wanted in the conſtruction of rail-ways for carrying the rail-road over rivers, ſudden valleys or roads; ſome of theſe may require caſt-iron arches; ſome of them muſt be of ſtone or brick; but oftener, ſuch may with propriety be conſtructed of wood, taking care that they are effectually truſſed, or formed on the beſt principles, alſo that the joints are effectually ſecured from wet, and the whole covered with a coating of mineral tar or paint, to be renewed from time to time to keep out the weather. One other thing remains to be mentioned reſpecting bridges, i. e. owing to the contraction of the canal and curvature of the towing-path at a bridge, the towing lines are apt to fret and wear away the corners of the bridges, occaſioning alſo a great waſte in ropes: for remedying this, light hollow cylinders of wood are placed upright, or nearly ſo, according as the wall is upright or battering, at all the corners of the bridges or other obſtructions to the direct line of the towing-path; theſe cylinders being hung on centres or pivots, at top and bottom, they turn round by the action of the rope, and prevent friction and wear.

The *Towing-Path*, horſe-path, or hauling-way of a canal, ſhould always be on the lower ſide if practicable, the traffic on the ſame having a tendency to conſolidate the new made bank, to prevent the accumulation of weeds and the harbour of vermine, that by lodging in and perforating the bank might endanger the ſame. The towing-path ſhould change as little as poſſible from one ſide of the canal to the other, and when this is unavoidable, it ſhould be always done at ſome fixed bridge, to avoid the inconveniencies before pointed out; the change ought never to be made in deep-cutting, as has been done near Tring on the *Grand Junction*. The towing-path ought never to be interrupted if the ſame can be avoided; and, beſides having a way under all bridges (except thoſe where a change of ſides is to be made) we hope to ſee the example followed, which has been ſet at Atcham on the *Shrewſbury*, and Newbold on the *Oxford* canals, of continuing the towing-path through the tunnels, wherever the ſame ſhall appear practicable. On the propoſed *Bude and Launceſton* canal, it was intended to form a towing-path on both ſides; a hint that may prove very uſeful in ſome ſituations of greater traffic, than there ever was likely to be on this canal. It is often provided in the act, that the towing-path may be uſed by the owners and occupiers of land on the line as a bridle-way, or as a drift-way for their cattle; as on the *Aſhby de la Zouch, Grantham, Leiceſterſhire and Northamptonſhire Union, Oakham*, &c. Frequently, permiſſion is given to perſons to uſe the towing-path as a foot-path or bridle-road, and we think it would in ſome inſtances be proper to obtain the power of levying a ſmall toll on horſe paſſengers; if the company ſhould at any future time ſee it right by public notice to permit their towing-path to be ſo uſed. It ſeems inapplicable to the purpoſe of a towing-path, to make public drift-ways of them in any caſe, on account of the damage which looſe cattle would do to the banks and fences, and the impediments which droves of cattle would preſent to the hauling-horſes and lines. In forming the towing-path, care muſt be taken to make the ground ſound, and to cover it with a proper thickneſs of good gravel; and we cannot but recommend the raking or ſorting of this as it is laid on, throwing the large or irregular ſtones forward to be covered with better gravel, ſo that the ſurface may be ſmooth and even, without rough and large ſtones to throw the horſes down, and render the uſe of the path unpleaſant. On the duke of *Bridgewater*'s canal, where proper materials for road-making are very ſcarce, the ſhale and ſlates, or refuſe coals from the mines are brought out and calcined, or burnt in very large heaps, the cinders of which are uſed for making and repairing the towing-paths upon his canal. The height of the towing-path ought not to be leſs than one foot, or more than two or three feet above the ſurface of the water, or top-water line.

The *fencing* of the ſides of a canal is a buſineſs deſerving of more attention than has been uſually paid to the ſame. Quick-ſet or other live fences ought by all means to be made, except in the caſe of a rocky country, where good and durable walls can be built at an eaſy expence: rail or pale fences are very improper, except in and near towns, on account of their heavy expence in repairs. The continual weeding which quick-fences require, the great injury which the plants ſuſtain from weeds, if the ſame are at any time ſuffered to grow up, and the damage which the pulling or hoeing up of weeds ſo repeatedly, do, in wearing away the ſoil, and more or leſs expoſing the roots of the quicks, and beſides theſe, the plants being often wounded in their tender bark by the hoes uſed by the weeders, are moſt ſerious difficulties in the raiſing of quick-fences, wherever our experience has extended, except in the north-eaſtern parts of Norfolk, where the ſpirited and intelligent tenants, that there abound, have a method of raiſing fences, which they are continually doing during the currency of their leaſes, that we are happy, in this inſtance, of being able to mention, becauſe it has not yet, we believe, appeared in print. The line of an intended hedge and ditch being marked out, the firſt ſtep is to collect carefully all the top-ſoil or vegetable mould into a ridge where the centre of the bank is to be, and if this vegetable mould proves too abundant, the extra quantity is thrown into heaps further off, in order to be mixed with dung, or carted to ſome parts of the land, which wants a greater ſtaple of mould. This done, a row of ſpits or lumps of earth out of the ditch are laid carefully in the front of the bank, and on theſe, when reduced to a regular line by paring with the ſpade, the white-thorn ſets are placed a little inclining upwards, at about four or ſix inches apart; care is taken in laying in the ſets, that their roots are bedded in the vegetable mould, that is to form the centre of the bank; when this is done, another row of ſpits or lumps is dug out of the bottom of the ditch, and laid upon the quicks, which being patted down and levelled at top with the ſpade as before; another row of quick-ſets is laid in, taking care that each plant in the upper row is over a ſpace in the lower one, and that their roots are incloſed in the top-ſoil. Other ſods are then dug out of the ditch and piled up, with the proper ſlope or batter, until the bank is raiſed to the intended height; the vegetable mould is then dreſſed up into a regular bank at the back, and the remainder of the

ſtuff from the ditch is thrown over, and is afterwards carefully ſpread and laid up againſt the back of the bank, ſo as entirely to encloſe the vegetable ſoil in a caſe of dead earth, or ſtuff taken from below, where cultivation has depoſited the ſeeds, or nature the viviparous roots of ſuch plants. Still further to accompliſh this excluſion of the ſoil in the bank, from the action of the ſun, air, and other ſtimulants to vegetation, at a proper ſeaſon in the ſpring, a quantity of dead earth is pared up from the bottom of the ditch, and worked and chopped about, until it is in the ſtate of *puddle*, before deſcribed. The tops of the quicks are cut off nearly even with the ground, after which, a labourer carefully plaſters every part of the face of the bank with this prepared or puddle-like ſtuff; and after it is laid on, having a pail-full of water at hand, to wet his ſpade in if neceſſary, he works this plaſter about, giving the flat ſurface of his ſpade exactly the circular and plaſtering motions that plaſterers uſe when at work on a ceiling or wall. If it ſhould appear that froſts have mouldered down, or injured the facing of the bank, the ſame is carefully repaired and worked again, as above, before the ſeaſon for the vegetation of the quicks. As ſoon as the white-thorns have put forth their leaves in the ſpring, a careful labourer walks along the ditch, with a knife in his hand, and wherever a plant is miſſing, from among thoſe which have ſhot forth, he digs in the point of his knife with care, to find and releaſe the top of the ſet, which otherwiſe might be ſmothered and confined by the plaſtering of the bank. The benefit of this procedure is inconceivably great, in almoſt totally preventing the growth of weeds, and in confining the moiſture in the vegetable mould from eſcaping in dry ſeaſons. At a time in the ſummer, when every part of the ſurface was covered with vegetation, we have with pleaſure examined ſome miles in length of quicks treated in this manner, and although the quicks had made the fineſt ſhoots which could be imagined, not a veſtige of vegetation of any kind beſides was to be found on the bank; and thus, with proper care in renewing the plaſtering or working of the bank, many of them remain until the quick is grown up to be a fence; and it is almoſt literally true, that weeding is here unneceſſary, although no ſoil can be more congenial to, or worſe ſtored with the ſeeds of annual weeds, than ſome of thoſe were of which we have been ſpeaking. The ditches are made deep, and the ſides of them as ſteep as the ſoil will ſtand in the general, ſo that dead or guard fences are generally omitted on that ſide; and ſo they are often on the other, or back ſide, and a prick-hedge is ſubſtituted, which, with care, and the letting of ſheep only looſe in ſuch fields, anſwers the purpoſe very well. Some time before the bank is made up to the intended height, the labourer goes along upon the top of it, ſhovels off the looſe top, and treads down the top of the bank ſo as to form a flat of perhaps 12 or 14 inches wide; into the centre of this he ſtrikes in his ſpade, and gives the ſame a lunging motion, ſo as to open a narrow and deep notch; this operation he repeats, until a notch of this ſort is opened the whole length of the bank; he then proceeds to ſtick this with ſhort and rough buſhes, ſo cloſe as to make a complete hedge; he then throws up out of the ditch as much ſtuff againſt the buſhes as will lay on the plane or top, in which the hedge is ſtruck, and beats the ſame down ſtrongly with his ſpade; the ſame proceſs is followed at the back of the hedge, by which theſe buſhes are ſo ſecurely ſet into the bank, that they will often ſtand until the quick is become a fence; in places where the deſtructive pilfering of the poor is properly repreſſed. Some may perhaps conſider us as going here too far into the ſubject of fencing, but we requeſt of ſuch to conſider how important the ſubject is to a canal-company, which may have to raiſe much more than a hundred miles in length of quick-fences, as was the caſe a few years ago with the *Grand Junction* canal company, and ſome others, ſome of whom are ſtill feeling the very heavy burden of weeding their quicks two, three, or four times annually; which an adoption of the above principles would, we are certain, have tended to reduce moſt materially. See our articles INCLOSING, FENCING, &c.

The quick for a canal ought to be placed a little above the level of the towing path, and be ſeparated therefrom by a ſmall ditch, to prevent the towing-horſes from biting or trampling on the quick; but the principal ditch, where the ſudden falling away of the off-bank does not anſwer the ſame purpoſe, ought invariably to be on the field ſide, for keeping the farmers' cattle at a proper diſtance from the quick, and to check their attempts at jumping through or over it. The quick ought not to be placed too near the towing-path. and the hedges ſhould be carefully cut and plaſhed about every twelfth year, both to preſerve them vigorous and in good growth, and alſo to preſerve the towing-path clear. On the *Oxford* canal, near Braunſton, we remember that the hedges were ſo grown over the towing-path, in the year 1799, that it was quite dangerous riding along, and the horſes were driven ſo near the edge of the canal, by the intruſion of the buſhes on the path, that the bank was ſuffering materially. In places where the canal is embanked, it will be proper to place the hedge at the bottom of the ſlope, in order to enable the company the better to prevent the growth of rank and large weeds, and the conſequent harbouring of vermin, which would lodge in the bank: ſteep embankments might alſo be materially damaged by the treading of cattle on their ſides. Through common fields, or very large paſtures, it is ſometimes not neceſſary to fence off the towing-path therefrom, but at the boundaries or entry to ſuch fields, a gate is placed in the towing-path, to prevent the intermixture or eſcape of the cattle; and generally theſe gates are double, falling rather forcibly towards each other, by which conſtruction the cattle are prevented from puſhing, or the wind from blowing open the gates, as would otherwiſe often happen.

At the termination of every principal eſtate or farm that adjoins the towing-path, it is uſual to place a ſwing gate acroſs the ſame, to prevent cattle getting away, in caſe they ſhould break, or by accident get into the towing-path. Cylinders ſhould be placed, as before deſcribed, againſt each of theſe gates for the towing-line to run upon; and ſide rails ſhould be placed inclining up to the top of the poſts, to aſſiſt the rope in getting over the ſame.

Draining is another expenſive buſineſs, of which a canal company will have a good deal to perform, in moſt caſes. Soon after a canal is filled with water, and often ſooner on the upper ſide, owing to the courſe of the land-ſprings, and thoſe of a more permanent character being intercepted by the puddle-ditches, wet places will appear on the land, which would, if neglected, become unfit for cultivation; theſe are often of conſiderable extent below the canal; and the committee of the canal company muſt not be ſurprized at hearing the farmers attribute many wet places in ſuch ſituations, to the ſoakage of their canal, that really are not affected thereby. It would be of uſe, and the ſource of much ſatisfaction, if the reſident engineer were to note down in his book all the wet and ſpringy places that appeared on the ſloping land, below the level of the canal for a conſiderable diſtance, and the condition or run of water from each before the canal was made; becauſe the appearance of new queaches, as the farmers in many parts call them, or the increaſe or enlargement of others, is often the firſt and only indication of

an increasing and hurtful leak from the canal. The committee should not be nice in drawing the line, as to the extent of draining which they order to be done; but it would, on the contrary, be highly to the credit of their concern, and the interest of future canal schemes, to bear the whole or a portion of the expence of effectually draining all the land, whose wetness could, even in mistaken prejudice, be ascribed to their canal. The execution of these operations ought not to be confined to the quackery of boring a hole here and there in a trench, without any theory or meaning; but the resident engineer, or some professional man employed expressly for the purpose, should, by a judicious application of his experience and knowledge of the *strata* in every place, apply that particular method of draining, as to the situation and depth of the drains, &c. which every spot may require. And these operations are more various and important than what any person, who has not made the subject his particular study, can possibly be aware of. See our article DRAINING. There is a danger attending drains made near a canal, from rats or moles working their way unobserved beneath the surface, between the drain and the canal; for detecting which, or other leaks, it will be proper for the resident engineer to enter in his book a minute description of the situation of the mouth or vent of every drain, choosing situations for the same, when they are made, in ditches, where they can be readily got at, and not be liable to be damaged by time, or the treading of cattle. The length and direction of every branch of under-drain which vents at that mouth, should be noted down, and the quantity of water which the drain discharges should also be carefully estimated, at some short distance of time after the same is finished; and a regular and periodical inspection of these drain-mouths by the engineer with his book in his hand should be made, by which any secret leak could hardly fail of being detected. It is almost unnecessary to point out the importance of an attention to these circumstances, in situations where water is very scarce.

The *construction of Boats* for canals and rivers requires some notice in this place. Mr. *Chapman*, who has given some excellent directions respecting the form of boats least liable to overset or be injured by heeling, has very properly observed (*Observations*, p. 102.), that the area of a cross section, of a boat to be used on a canal, ought not to approach so near to the area of a cross section of the water in the canal as 1 to 3, or considerable inconvenience will arise, both from the increased resistance of the boat, and the damage to the banks, from the counter current to fill up the space the boat leaves in her rear. This circumstance requires particular attention, particularly in boats that are to move quick, like the passage-boats from Manchester and Paddington, on *Bridgewater*'s and the *Grand Junction* canals: in the former of these, we observed a constant elevation of the water before the passage boat, as it moved along, of at least 9 inches, and perhaps more than a foot at times; and the rapidity with which the water ran backwards, between the boat and the sides of the canal, appeared to have a most destructive effect upon the latter, particularly on the towing-path side; and often this was laid quite under water, for considerable distances together, by the surge or wave opposite to the head of the boat as it passed along: while the labour of towing was most materially increased. We regret that we had not the means of ascertaining, how much the head of the boat was elevated upon this artificial wave in the general, and up which inclination the towing mules were constantly drawing it. Some attention ought to be paid to the form of the head and forepart of the boat, with a view to its letting the water pass freely off by its side: flat headed boats, and those whose ends are rectangular in particular, ought not to be towed fast, or great loss of labour and damage to the banks will be the consequence, unless the canal is very wide and deep. It has been proposed to form boats sharp at one end and flat at the other, so that the flat ends being joined, two of them may form a body, diminishing properly at each end, for easy passage through the water, and for steerage. Mr. *Nicholas King*, an American, has proposed boats in four parts, that can be detached when the same are to pass an inclined plane, and be afterwards rejoined. Since the use of cast-iron has become so general, Mr. *John Wilkinson* has constructed boats and barges of iron, some of which are used on the *Severn* river, and others upon the different canals in Staffordshire, Worcestershire, &c. Mr. *Robert Fulton*, in his *Treatise*, p. 31, has proposed and described a kind of rectangular boxes, with low wheels (or rather trucks, as the axle and them are to be cast in one piece) fixed under their bottoms, to be used upon canals instead of boats, on account of the use which he proposes to make of them, upon inclined planes and rail-ways, as well as on the water, as we have before mentioned. Mr. *William Chapman*, who has examined this system particularly, in his *Observations*, has proposed and given drawings of wheeled-boats of a different construction, larger wheels let into the bottom of the boat being used; and his boats are so contrived, that several of them, linked together by their ends, can be used together either upon a canal, or a rail-way, or plane. The same author has recommended and described a kind of flat-bottomed boat, with a single or double rail-way on its floor, which he proposes to receive or discharge a loading of rail-way waggons, as it lies in a shallow dock, from which the water has been drawn, and to which it is to be again admitted when the boat is to float out into the canal. For ease in getting loaded waggons in and out of these boats, a pair of leaves, or water-tight flaps, are contrived to let down, and permit the junction of the fixed railway on the land and the part thereof that is on the floor of the boat. A curious method of steering boats is in use on the Bedford, *Ouse*, the *Cam*, and others of our eastern rivers: two boats are always used together, one of them having a strong pole, or bowsprit, projecting horizontally from above its prow; this is brought over the stern of the boat which is to go before it, and the prow or stem of one boat is fastened by a rope close to the stern-post of the other; to the first boat the towing-line is fixed, and the bowsprit of the last boat is used as a tiller to set or retain the last boat to any required angle with the first, by which the last boat acts very effectually as a rudder for steering the first. Mr. *Chapman* proposes to adopt this principle with small boats upon canals. The west-country bargemen, on the Thames, guide or stop their boats, as they are floating down the stream by a long and strong pole, with iron prongs at bottom and a cross handle at top, round which they dexterously wrap a short rope, fastened to the side of the barge, when the pole has struck into the bottom of the river.

For speedily emptying the cargoes of small boats into larger vessels, Mr. *Davis Dukart* contrived, on the navigation to the Dungannon Collieries, to float his small boats on to cradles or wheeled carriages, on which they were dragged up a short inclined plane, and upon a rail-way conducted over the barges in the bason; and then the boats could be turned over, and their contents shot at once into the barge. A different method, as Mr. *Chapman* informs us, is practised in South Wales: it consists in continuing the canal (which may be a wooden trough) to the place of discharge, and terminating it on a caisson, suspended on a transverse centre; the boat being arrived at its place, the end of the canal is

closed by a stop-gate, and the small quantity of water contained in the caisson (which the boat should as nearly as may be fill) being let out, the caisson with the boat in it may be turned over, as already described.

The *moving of Boats* upon canals or narrow rivers, where sailing is impracticable, has always appeared attended with considerable difficulties. Where the width and depth of water will admit, long oars have been used, worked by one or two men on each side of the vessel, as is done on the coal-barges and lighters on the *Thames* in or near London. On the *Tyne* river at Newcastle, their keels are said to have been in use ever since 1378, and are rowed by an immense oar *on one side*, another being used at the stern to steer by, and counteract the tendency of this strange mode of rowing. It is said that the large oar is hung by an iron ring, so as to admit of its being laid on the gunwale of the keel, when not in use, but not of its being removed. Owing to the want of any regular and proper path on which horses could travel by the sides of rivers, the first hauling or towing of boats was performed by men, as still continues to be the case on the canals of China; and in this country most of our navigable rivers were without horse towing-paths till of late years. Within our recollection, ten or fifteen men were seen tugging at the hauling line of a barge on the *Thames*, in the meadows of Twickenham. A good horse-path now begins at Putney bridge, on the south side, and continues uninterruptedly on one side or other of the river to the extreme points of the navigation. These essential appendages to navigation are but now completing on the *Severn* river, which has been so long famous for its navigation. The towing-path on many of our old navigations is continually interrupted and broken off, by mills and other obstacles, without any bridges for the crossing of the towing-horses and boys. On the *Ouse* river, below Bedford, we have observed the towing-path to be interrupted at the end of almost every field, by high and dangerous stiles, over which the ill-fated navigation-horses have to leap, encumbered by their harness and the heavy rope. No regular path is maintained, in a great part of the distance, by the owner of the navigation; but frequently the fine meadows there are cut up, by the track of the horses being at a considerable distance from the river, across the many bends that it has; and the farmer's grass, between this path and the river, is rendered of little value, by the soiling and dragging of the hauling-rope over it; the banks of the river are also miserably worn away, by hauling so far from, and consequently so obliquely to, the direction of the stream. In many places, where the river is wide, there is no track for hauling, except along the bed of the river itself; where often the horses, with a wretched boy upon one of them, are seen sometimes wading, and at others swimming, along the course of the river! Nothing is more common than seeing the horses and boy have to swim over from one side of the river to the other, when the hauling-way changes; not unfrequently this is impracticable, from the total want of a way on either side, and the poor horses are obliged to leap from the bank, perhaps when at a considerable height and distance, into the head-room of the barge, to the great peril of their bones and neck: shortly after, these wretched animals, and probably with a boy on their backs, are forced to jump out again, and perhaps plunge into the deep river and swim on shore, to resume their labour of towing. A correspondent of Dr. *Anderson* has expatiated (*Recreations*, v. 318.) on the barbarous sight of six horses harnessed at length, towing a barge up the *Thames* above Putney, by a single line of insufficient length, by which the hind horses were in continual danger, in spite of their utmost exertions, of being precipitated into the river: what would this humane gentleman have said, if his walk had been along the banks of the *Ouse*, on a piercing winter's day? It is owing, in a great measure, to the enormous difficulties and expence of constructing and maintaining a proper horse-path by their side, that the navigation of many of our rivers is so imperfect. In all flat countries, except the river is embanked, as in Cambridgeshire, Lincolnshire, &c. and without any wide wash or fore-ground within the banks, the towing-path often cannot be made up above the reach of the floods, but, during every floody season, will be under water and useless; and perhaps, when the water subsides, it will be found carried away by the force of the current for great lengths together. On some of our canals, the practice at first prevailed of towing by men; and the same still continues on the *Stroudwater* canal, whose towing-path has *stiles* upon it, like those of a foot-path, at the divisions of different persons' lands. Horses are now, in general, used for towing boats on our canals, except the late duke of *Bridgewater*'s, who reared a large and fine herd of mules, that were found to answer so well, that none others are used to this day, we believe, on that canal. Except with passage-boats, and flies or packet-boats, for the expeditious conveyance of packages and parcels, the usual rate of tracking or towing upon our canals is about 2½ miles per hour, including the time lost in passing the locks, which, if of 8 feet rise, will require about 5½ minutes each.

It is certain that there is hardly any limit to the load, which one horse can move, in a number of barges attached together, when going with a proportionally slow pace; and this has occasioned some canal advocates to assert that one horse will, on a canal, draw as much as 60 on the road; while Mr. *Robert Marshall* has asserted, that horses will not be able to move more than 15 miles per day with deep laden barges on a level canal. On most of the wide canals it is usual to employ a horse to each barge, or to a pair of boats of half the width each that the barges are. It appears, that on the *Ketley* canal, on *Bridgewater*'s canal between Worsley and Manchester, and others, several of the small boats in use thereon are linked together, and drawn by one horse or mule; there being projecting and smooth rails provided on the *Ketley*, at all the convex points of the banks, to keep the boats in their proper track. Mr. *Fulton* has imagined, that 15 or 20 of his small rectangular boats, linked together, could be drawn by one horse, and be kept in their proper line upon the canal by a man with a boot-hook walking by the side of them on the towing-path. Besides the methods of rowing and tracking, which we have been mentioning, on the *Tyne*, the *Thames*, and most of our rivers, hitchers, sets, puys or poles, are used for shoving of barges along: the gunwale of the keels or barges is made wide and convenient to walk upon, and the boatman, being at the head of the barge, sets his hitcher against the bottom and shoves against it, walking along the gunwale of the barge until he has arrived at the stern; when he draws up his hitcher quickly, and returns to the head to repeat the same operation, and this sometimes on one side of the barge and sometimes on the other, unless there are two men so employed, whose equal action could keep the barge in its direct course. This last method might be more used than it is upon canals; but from the necessity which most of them have found, for prohibitory clauses in their act, against the use of any pointed poles, particularly such as are shod or tipped with iron, on account of the damage which such often do, by penetrating and disturbing the lining and banks of the canal, and causing it to leak. We have heard of an attempt lately, to introduce a kind of hitcher-iron on the *Grand Junction* Canal, which should present a flat end or surface, sufficient to prevent its penetrating the facing on the bottom or sides of the canal, and having a small turn up at

the point, which might remedy the loud complaints of the boatmen, at being debarred a hooked pole on board their boat, by which a comrade, who has the misfortune to fall overboard or into a lock, might be dragged up to the surface of the water. We have thought that it might be worth while, particularly in crooked and difficult parts of a canal for hauling, and where rubble stone or gravel is in plenty, when a wide canal is cutting, to form the covering of the lining, or the facing of the bottom, and perhaps of the lower part of the sides also, of gravel or rubble instead of earth, and carefully to level and ram or roll the same down like a road, so that hitchers might be used freely thereon as on the bottom of a river. There would still, however, require very strict and well enforced regulations, to prevent the walls of the bridges, locks, tunnels, &c. from being pecked and greatly damaged by the points of the hitchers. Slide-rails will also be necessary, in and near the locks or tunnels, as we have mentioned in speaking of the Blisworth tunnel, which can, without damage to the walls, be removed, when decayed or worn out. Before we proceed to the subject, that has perhaps produced the greatest number of unpractised mechanical inventions that are any where else to be found, we mean for *moving boats* by an impulse from within or accompanying them, we have one other thing to mention, viz. that Mr. *James Jordan*, in his patent of the 24th of May 1796, for bridges, before quoted, has proposed the use of circulating chains across an aqueduct bridge, for towing boats over the same; and avoiding the expence of the extra width for, or lateral support of, a towing-path thereon.

The volumes of the *machines approved by the Academy at Paris*, and the *cabinet* of *M. de Servier*, printed in 1719, contain plates and descriptions of many different contrivances, designed for *propelling or rowing of boats* on canals and rivers; one kind of these, which we shall first notice, depends upon gaining an impulse or hold agaist the ground at the bottom of the river or canal; in one of which, a small boat moved by oars was proposed to be employed in successively carrying forwards and dropping anchors whose ropes were to be attached to a horse-gin on board of a barge, which was designed to tow or drag a great number of others. In another, a spiked wheel was proposed to roll on the bottom of the canal, attached by a frame moveable on hinges at the stern of a barge, where a roller turned by a winch, was to give motion to the spiked wheel and propel the barge, by means of an endless rope or chain. See also *Walker's Lectures*, 4to. page 350. A second kind depended upon the same principles as an oar, except in the construction and mode of applying the power. On the 20th of July 1796, Mr. *Thomas Potts* took out a patent, for the use of a large flap or oar, moving on an horizontal hinge, upon a framed lever at the stern of a barge, intended when the handle of this lever was lifted up by several men, to turn on its hinge and present but little resistance; but on the descent of the lever, its whole surface was by the action of the men at the lever, to be exerted on the water for propelling the barge: see *Repertory*, vol. vi. p. 160. In the year 1801, Mr. *Edward Steers* took out a patent, of which we have seen only a short extract in the *Monthly Magazine*, vol. ix. p. 486, from which we understand his invention to differ but little from the above, except in having two paddles or oars. Mr. *Robert Beatson* took out a patent, for applying the principle of luffer-boards or venetian-blinds to several purposes, which he has explained at length in his *Essay* printed in 1798; and at page 60, proposes to propel ships by large oars or fins of this kind to be hung on the sides thereof by hinges, and worked by a lever, as a rudder is by its tiller; poles with square frames fixed on their ends, to push against the water behind the vessel are also described. A third kind, depending on the reverse of the action of an undershot water-wheel, has had many advocates; the first that we have met with in our own country, is Mr. *Thomas Savery* in 1698, whose contrivances are shewn in *Harris's Lexicon Technicum*, art. Engine; it consisted of 6 or 8 paddles like those of a water-wheel on each side of the vessel, fixed on an axis across the same, on which was a trundle head, and under this a wheel working into the same, by the force of a capstan to be turned by men. We are told, that in the year 1781, the *abbé Arnal* proposed to apply the power of a steam-engine on board of a vessel, for working paddles, something like the above, we believe. Soon after this period, we remember seeing on the shore of the *Thames* at Westminster, a small barge with a water-wheel in a cavity in its stern with a steam-engine for working it, which was said to be the contrivance of *earl Stanhope*, and had been tried with success against the tide in the river. In the year 1797, a vesse having rowers by its side, that made 18 strokes per minute, from the action of a steam engine on board, was tried on the *Sankey* canal near Liverpool, by which it was propelled 10 miles and back again to the same place: see *Monthly Magazine*, vol. iv. p. 75. In the same year, Mr. *Walker* (the lecturer) made some experiments on the *Thames* at Reading, and caused a boat to row itself against the stream. See his *Lectures*, 4to. page 349. About the year 1800, *Messrs. Hunter* and *Dickinson* took out a patent, for a propeller for ships, which was tried in January 1801, on board of a government sloop off Deptford on the *Thames*, and the sloop thereby made way against the tide at the rate of three knots an hour. *Monthly Magazine* vol. xi. p. 195. In the *Journals of the Royal Institution*, about the year 1803, there is a description of an improved application of the steam-engine, to the turning of a wheel for propelling boats; the cylinder of this engine is horizontal, and the wheel with paddles is in a cavity in the stern of the boat, which therefore has two rudders, one on each side of the wheel, connected together by cross rods. A vessel of this kind was constructed for the *Forth and Clyde* canal company, under the direction of Mr. *Symington* the inventor, and in a trial made in December 1801, it drew three vessels of 60 or 70 tons burthen each, at the rate of 2½ miles per hour on their canal: see *Agricultural Magazine*, vol. vii. p. 152. We read in the last mentioned work, vol. ix. p. 218, that Mr. *Robert Fulton* exhibited a vessel on the *Seine* at Paris, in August 1803, having two wheels with paddles, worked by a steam-engine, and that two other vessels were towed by it against the stream at the rate of 3 miles per hour. A fourth kind of boat propellers, has depended on the rotary motion of a screw, or fliers like those of a smoak-jack; Mr. *Daniel Bushnel*, in his attempts to navigate sub-marine vessels, as related in the *Transactions of the American Philosophical Society*, vol. iv. p. 303, used oars, placed near the sides and top of the vessel, formed upon the principle of a screw, the axles of which entered the vessel, and by turning the same one way, the vessel was made to advance or descend, as it was to recede or ascend by a contrary motion of the screw. Mr. *John Vidler* has contrived a vessel, which has been lying, and occasionally tried in the *Thames* at Westminster, for 2 or 3 years past, that has a boom hung by an universal joint (Hook's) at the stern thereof, to a rotative axis, turned by a capstan upon the deck of the vessel; at the end of this boom is fixed a circle of strong flyers, just like those of a smoak-jack, which by striking the water obliquely as the boom is turned round, propel the vessel forwards; near to the flyers there is a collar on the boom that turns easily therein; to this collar ropes are

attached, which go to different parts of the ſtern of the veſſel, and by which the boom, when in motion, can be drawn up quite out of the water, if its propelling action is wanted to ceaſe on any temporary occaſion, or the flies thereof can be let down into the water to any depth which may be required, or be turned aſide from the direct line of the veſſel to ſteer her on any courſe, without waſting ſo much of the propelling power upon the rudder as is uſually done in ſteering; a rudder is however applied to the veſſel ready for uſe when occaſion may require. The fifth and laſt method, which we recollect to have ſeen or read of, conſiſts in pumping water, by a force-pump through an orifice or pipe at the ſtern, or end of the keel of the veſſel, with ſuch force as to propel the veſſel along, by the ſtroke of the moving column of water againſt the water, in which the veſſel floats; we are ſorry that our memory does not ſerve us to mention the name of the inventor of this method, or the work wherein we ſaw a deſcription of the apparatus. In the *Britiſh Magazine*, vol. i. p. 397, it is mentioned, that in the year 1800, a veſſel was conſtructed at Liverpool with a ſteam-engine in it, which was moved along without the intervention of any machinery; we think this as likely to have been, an application of the pumping principle above mentioned. Although, as we hinted above, none of the mechanic contrivances here mentioned have been adopted in practice, we truſt our readers will not be diſpleaſed, at the ſhort notice which we have given of each, with a view to preſerve their memory, and in hopes that the thing may yet be accompliſhed.

On the *repairing of Canals* we think it neceſſary to ſay ſomething; and to begin, by recommending the adoption of a ſyſtem of management, by which the ealieſt notice of any defect, or want of reparation, will be obtained: that in ſtorehouſes, at proper places on the line, a ſtock of oak, elm, and deal timber ſhould conſtantly be kept, cut out and ſeaſoned, ready for replacing any of the timbers or planks in the locks or other works, with the leaſt poſſible delay to the trade; a circumſtance which, if not attended to, may prove of incalculable injury to the credit and ſucceſs of the concern. Sound and good bricks, and ſtones, ready for replacing any which are liable, or obſerved to be likely to want repair, ſhould alſo be in readineſs, and good cement ſhould always be kept in readineſs, on ſome part of the line from whence the quantity wanted may be ſpeedily tranſported to any part where a reparation of the walls, bridges, culverts, &c. may require the ſame: however, before emptying any part of the canal, or interrupting the trade for any reparation, a ſtrict ſearch ſhould be made throughout every part in that level, or on the adjoining ones, to diſcover all the defects therein, that arrangements may be made beforehand for repairing the whole at once, or with as little delay as poſſible, while the trade is interrupted on the line. In every ſtore-houſe a conſiderable number of the *pile-planks* before deſcribed ſhould be kept piled up in readineſs, for making temporary ſtanks or dams, in order to empty any particular part of a level, which may have a culvert, trunk, ſluice, ſtop-gate, lock-ſil, or other thing which is damaged, out of order, or decayed. It is ſurpriſing, to thoſe who have not ſeen ſuch works performed before, with what facility the workmen who are uſed to this buſineſs will drive two rows of pile-planks ſo regular and cloſe to each other, that by the help of the tongues or ſlips in their grooves, and often without, a tight ſtank is made without any earth or other looſe matters to ſtop the water; and between two of theſe ſtanks, if ſuch are neceſſary, they will empty the water, by chain-pumps, or water-ſcrews, to get at any culvert, or other matter, to be repaired or altered; there have been inſtances of theſe operations being performed, and of the part being filled with water, and the plank-piles drawn up again for the trade to paſs, in the ſpace of eight or nine hours. Should any part of the canal appear to want new lining or puddling, owing to a neglect at the time of making of the canal, or to any ſubſequent accident, care ſhould be taken to chooſe the time for ſuch works, when the trade can beſt bear an interruption; and as, on the average of ſeaſons, the trade is two or three weeks interrupted by ice, during the months of January and February, it may not be amiſs to embrace that period, on ſome occaſions, although the work may be longer about, and ſome additional expence may be incurred by covering up the work with earth, before it is left at night, to prevent its freezing, and in removing all ſuch puddle, &c. again in the morning, or at beginning work, which ſhall be found frozen. Previous and explicit notices ſhould be given of all intended interruptions to the trade, as long beforehand as is neceſſary, to enable the traders to ſupply ſtocks of articles at the places of conſumption on the line, and to avoid having their barges locked in, and perhaps lying idle, when they might have been employed if they had been on a different part of the canal.

It is an eſſential point of good management to have experienced mole and rat-catchers employed from time to time upon the line of a canal, to extirpate theſe hurtful vermin; and in every inſtance of diſcovering one, to trace out all his burrows and holes, and have them carefully ſtopped up and filled in every part, as well for preventing the harbouring of other animals of the ſame ſort, as for preventing the water from making its way into and through them. On a canal in Surry, we are told by Mr. *Robert Marſhall*, in his *examination of a canal and rail-way*, &c. that a *mole* or *rat hole* only, occaſioned, after the hard froſt of 1795, the rupture of the canal in a high embankment, by which more than 100 yards in length of a lofty bank was precipitated into the meadows and river below, and that a barge which before lay enveloped in the ice on the canal, was hurried down through this gulph into the river! It is impoſſible to take too much care againſt ſuch fatal diſaſters as theſe, and the duty of the mole and rat-catchers ought not to be limited to the company's ground, but in all fields, banks, ponds, or brooks within 100 yards or more of the canal, on each ſide, they ought to be equally attentive to the deſtruction of ſuch vermin, and the demoliſhing of their ſecret retreats. The ſame men might very properly be employed in pulling up and extirpating all large and ſpreading weeds from every part of the banks of the canal, and in mowing down the herbage occaſionally; theſe circumſtances being not leſs eſſential for the neatneſs and beauty of the canal, than to prevent the firſt harbour of vermin of different kinds. The banks of the canal will be very apt to continual wear at the ſurface of the water, and for ſome height above and below that level, if a proper kind of herbage is not encouraged upon the ſlope of the bank: conſiderable care ſhould be taken to ſuffer no plants to take root on or near a canal bank, or ſpread its ſeed, (if poſſible to prevent it where water is taken into the canal by a feeder), which will grow in deep water, or whoſe roots are large, hollow, and ſtrike deep into the ground, leſt the former of theſe ſhould choke the canal in time by weed-beds, and the latter render it leaky by the formation of numerous open tubes through the lining into porous ſtuff. None but thoſe who have ſeen many drains or new ditches opened in wet and boggy ground, can be aware of the depth, ſize, and number of hollow roots, which ſome of the aquatic plants, as the *equiſetum paluſtre*, or marſh horſe-tail, the *iris pſeudacorus*, or yellow flag, and ſeveral others, ſend forth into the ground.

Puddle-ditches, in the banks that are raiſed or made up, are a great ſecurity againſt the bank being waſhed down,

in cafe of the water, rifen by any fudden thunder-fhower, or other inordinate rain, breaking over the top of it; as foon as the puddle is reached, the effect of the ftream to tear and lower the bank will often be ftopped; for good puddle, when properly fet and hardened in the centre of a bank, is fo compact as not to be liable to be abraded or fuddenly worn by a current of water. In cafe of the breaking or flipping of a bank, fo that a confiderable and wide breach is formed, and ftill increafing, it is a good practice to drive in two rows of common fold hurdles, at a foot or lefs apart, lafhing the fame well together by cords, and fecuring them by ftrong ftakes drove down behind them, and if the ftream of water be deep through the breach, it will be neceffary to drive other long ftakes obliquely into the ground, and fecuring their tops to the hurdles and upright ftakes by laps of cord, that thefe laft may act as ftruts to prevent the whole being borne away; into the cavity between the hurdles; ftraw or ftubble fhould then be put and trod down, beginning at each end and working towards the middle, in order to prevent the current being turned, with frefh impetuofity, againft the fides of the breach; fuch a dam as this will prevent the lofs of any confiderable further quantity of water, and will render the water ftagnant, fo that a row or more of pile-planks can be drove to cut off the connection with the breach, which can then be emptied of water, the hurdles and ftraw removed, and the reparation begun, with proper puddle-ditches for its fecurity, as before defcribed. At the famous Dagenham breach of the embankment of the *Thames*, dove-tail, or plank-piles were ufed, we are told. It will be neceffary to defend many places of the banks of a canal that are obliged to be unufually fteep, as in the approach to a bridge or lock, a wharf, &c. with a facing of planks, called *camp-fheeting*; this confifts of ftrong piles driven into the bottom of the canal, with the proper inclination, with horizontal pieces, or land-ties to their tops, on to which piles found and durable planks are fpiked. In fome places, owing to the accidental or unavoidable admiffion of very thick water into a canal, or in more cafes by the ordinary depofit in length of time, the canal will become choked with mud. In thefe cafes a machine with buckets, like a chain pump, to fcrape the bottom of the canal, and afterwards difcharge the load of mud into a barge, might be ufed, fuch a machine, worked by horfes, being now in ufe in the *Weft India Docks*. See alfo *Walker's Lectures*, 4to. p. 35. The late Mr. *Brindley*, we are told, contrived a plan for the purpofe of clearing the docks at Liverpool from mud.

By neglect it will fometimes happen in canals, that *Weeds* grow up from the bottom, and form an unfufferable impediment to the motion of the barges; and this is almoft unavoidably and generally the cafe in river navigations, if conftant care is not ufed to tear them up, or cut them down. On the great *Oufe*, and other fen rivers, a machine has been long in ufe, called a *bear*, for tearing up ftrong weeds by the roots.

About the year 1796, the *chevalier Bentancourt Molina* prefented to the *Society of Arts*, a model of a barge, having a windlafs in its ftern, which gives a circular motion to a pair of knives or fcythes, or a lever giving an alternating motion to knives for mowing off weeds clofe to the bottom of a canal, in which the barge is to float, or on the floping fides of the canal; for which purpofe, the knives can be made to revolve at any depth below the furface of the water, and either horizontally, or inclined in any angle; this model may be feen at the fociety's houfe in the Adelphi, and a defcription and view of it will be found in their *Tranfactions*, vol. xiv. p. 345. or *Repertory*, VI. 169. In moft winters it happens, that an ice not more than an inch or an inch and half thick, continues for a confiderable length of time on canals, and other ftagnant waters; this, or even a lefs thicknefs of ice is fufficient to ftop the trade upon canals, unlefs the ice is broken; and, for this purpofe, it is advifable, every morning of a froft, unlefs the ice fhould be found more than ufually thick, and the froft increafing, and likely to continue, to break the ice on each pound; this is ufually and effectually done by a ftrong and fquare headed barge, whofe floping or projecting head is covered with ftrong iron plates. One of thefe barges being drawn along the canal, and into each lock, by feveral horfes, has a conftant tendency to rife up upon the ice, and thereby breaks it down before the barge: about the lock-gates it will be neceffary to break the ice by ftamping with the end of a pole. Mr. *Symington*, whofe barge, with a fteam engine in it, to propel it along, and tow other veffels, we have lately mentioned, has provided the head of his barge with ftampers, to be worked by the engine, for breaking of the ice before it, in frofty weather.

Leaks in a canal may fometimes be ftopped without emptying the water, if the depth will permit it, by preparing good puddle in a flat-bottomed dirt-boat or flat, and dropping the fame in fpadefulls equally over the furface, and when a certain length is done, raking the fame about with a rake, with fhort teeth to join the pieces together, and level the bottom. The difference in fpecific gravity, in different loams and earths, is fo confiderable as to make fome of them much more proper for the lining and facing of a canal than others; the heavieft that can be found fhould be ufed when leaks are to be ftopped, and the water remain in the canal as above. We have paffed along the branch of a canal on a chalk foil, where the lining of the bottom was fo light, that the motion of the barge ftirred enough of it up into the water, which was before nearly clear, to make it almoft as white as milk behind us; this light ftuff has fince been taken out, and a fubftantial lining and facing of proper ftuff, brought in barges for the purpofe, and laid on the bank before the water was let out, has been applied, by an able engineer, who fucceeded thofe of too different a defcription who conftructed this very leaky branch.

Some *Implements* and machines are ufed in the making or working of inland navigations, which we have not had occafion yet to mention or defcribe. In every confiderable work it will be neceffary to erect rolling-ftones for grinding and preparing of the cement or mortar that is to be ufed in the water-works. At Worfley, on *Bridgewater*'s canal, the power of a water-mill is applied to turning feveral pair of large ftones on edge, like thofe ufed by tanners, gunpowder-makers, &c.; in fome of thefe the ftones rolled round on a fixed ftone, in others a large caft-iron flat pan, in which the materials to be ground were put, was turned round under the ftones, which were thus made to revolve round their own fixed axis on the materials. What appeared fingular in the procefs at this place was, that the lime and other ingredients were ground with water for a long time, in the ftate of thin mortar, which was then removed into cifterns to dry, and before the fame was become too hard, it was cut out by a fpade, into lumps of about half a cubic foot each, and heaps of them were preferved in a ftore-room, where they became quite dry, and as hard as chalk, or harder, for ufe at diftant periods of time, in the repairs of the walls and works under water. At the *London* and *Eaft India* docks fteam-engines, of twenty horfe power in one cafe, were ufed for grinding their cement; but the pozzolana, lime, and other ingredients are here mixed and ground together in due proportion in a dry ftate (as *Parker* and Co.'s patent Roman cement is done), and it is not wetted, but carefully preferved

from moisture, till a very short time before it is to be used in the walls, &c. See the article ROLLING-STONE.

The *driving of Piles* is a very considerable business in many large concerns; at the entrance of the *London Docks* a steam-engine was erected for driving the vast number of piles which were required for the coffer-dam. Mr. *S. Bunce* contrived a very simple and effective kind of pile-driver, to be worked by men at a winch. Mr. *Harvey* contrived a double pile-driver, which is described in the *Transactions of the Society of Arts*, vol. xii. p. 337. The horse pile-driver contrived by M. *Vauloue* cannot, from the almost innumerable models, plates, and descriptions which have appeared of it, since the building of Westminster Bridge, be unknown to any of our readers. Mr. *John Fould* contrived a machine, and presented a model of it to the *Society of Arts*, (see their *Transactions*, vol. xiii. p. 280) for cutting off the tops of piles, after they have been drove, beneath the surface of the water. See the article PILE.

Some of the navigator's tools and implements, as barrows, horsing-blocks, grafting-tools, shovels, and scoops, we have represented in *figs*. 48 to 52, *Canals, Plate* VII.

Cranes for the hoisting of goods will be required on the wharfs of canals and rivers. See our article CRANE.

On the *general management*, and office department, of a canal concern, it is unnecessary to enlarge. The committee with which the conduct of it is entrusted will, without doubt, direct their attention to those various circumstances on which its prosperity depends. Accordingly, they will appoint proper officers in the several subordinate departments, and give them such instructions for the regular discharge of their duty as occasion may require. It may not, however, be improper to suggest, that the canal committees should direct their resident engineer to establish proper rain and evaporation gauges at several lock-houses upon the line, to be kept by the lock-keepers, and registered daily or weekly with great care: these observations, preserved in the company's books, or, what would be better, published in some of the magazines, would prove of great advantage to science, and to canal undertakings in general. In canals of considerable length, particularly if some parts of them are indifferently and variably supplied with water, or leaky, it will be right to fix gauges or graduated rods on each upper lock-gate, that would shew at all times how many inches depth of water there is at the time, in the shallowest part of that pound; and to cause the lock keepers to mention the same at the foot of the printed permits or pass tickets, that the toll-clerks should give to every bargeman who passes, containing the number and description of each barge, and the description and weight of its loading; these, transmitted regularly to the toll collector, would enable him, or some other person, to keep for the information of the committee, a register of the daily state of each long or leaky pond of water; at the same time that the lock keepers, toll-clerks, &c. at each extremity, and on different points of the canal, would always be acquainted with the state of the water, and the loading which a barge could pass with at every particular place; and could inform bargemen; for want of which knowledge great delay and expence are often incurred, in dry seasons, by setting off with more lading than can be carried through, for want of a sufficient depth of water, and part of the same is obliged to be left on the road, or taken into other boats. All the regulations contained in the act, for working of the canal, and such by-laws as the committee may see it necessary to make, for regulating the conduct of the bargemen and others on the canal, should be printed, and stuck up at every wharf on the canal, and in every toll-clerk and lock-keeper's house; and all the company's agents and servants should be strictly enjoined to notice every breach of laws and regulations, not by altercation with the offenders, but by immediately noting down in writing the exact and true particulars of the time, place, and name of the offenders and bye-standers or witnesses, &c. transmitting the same immediately to the committee, and preserving a copy thereof themselves: and, though we are far from recommending severity in punishing on these occasions, yet a system of this sort, by shewing the offenders that the committee would always be prepared to proceed against them, would, in most instances, especially if the parties were written to, to threaten them, go a great way to prevent the same parties or others from offending again.

Tonnage Tables, fully and explicitly stating the toll or tonnage payable to the company, on goods or articles of every different kind, or on different parts of the line, if, as often happens, these vary, should be printed and stuck up on all the wharfs and toll-houses, for preventing all doubts or altercations between the company's servants and the traders. At some convenient place on the line of the canal, a *weighing-house* should be prepared, consisting of a dock under cover, large and deep enough to contain the largest vessels which are to navigate the canal; this dock should be furnished with a draw-gate to let down, or doors to shut, when an empty barge has entered, in order to render the water quite still within the dock. Cast-iron or leaden weights of 2 cwt. each should be provided, and a crane to hoist the weights readily in or out of the barge, and place them in any part of the same, so as always to load her evenly. To this weighing-house, the act or by-laws should require every barge to be sent, having the name thereof, and the owner's name and residence previously painted on the stem of it, before it is allowed to trade on the canal: the empty barge being arrived in the dock, the gauging-master fixes four small plates of iron, each containing the *number* that this barge is in future to be distinguished by, two on one side, and two on the other, against the gunwale, near the head and stern. These plates are all fixed at the same distance from the surface of the water, when the barge is empty; this distance, in inches and tenths, is entered into the gauging-master's book, under the number of the barge, name, owner's name and residence, date, and other particulars; two tons of weights are then hoisted into the barge, and regulated until the distance from all the four plates to the water's surface is the same, which distance in inches and tenths is also entered in the book against two tons; two tons more of weights are then hoisted in and adjusted, and the height of the number-plates above the water is taken and entered against four tons as before; these operations being repeated until the utmost lading of the barge is on board, when the weights are taken out again, and the barge removed from the dock. For measuring the height of the plates at the Paddington weighing-house, a tin tube is used, that is furnished with a float moving freely in it, to mark the surface of the water, which carries a light stick graduated to inches and tenths, to show the height of the number-plate against which it is applied. At every toll-house on the *Grand-junction* canal similar floating-rods are kept, and to every laden barge which passes this gauge is applied against the number-plate, at each end, and to those on the other side, if the barge appears to heel at all to either side. If the dry inches and tenths shewn by the gauge, between the number-plate and the water's surface, are different, they are added together, and divided by the number of them for the mean height. It is the business of the gauging-master to calculate, from the particulars entered in his book, of each barge as above, the weight to the nearest of ¼ of a ton, which answers to every inch and

tenth of an inch, of the dry inches ſhewn as above by the gauge; the number of the barges are applied in a regular ſeries, in the order in which they come to be gauged; and a book, containing a table for the tonnage on board, anſwering to every dry inch and tenth, as above, is calculated, and a copy of each is in the poſſeſſion of each toll-clerk, by a reference to which, he ſees and enters in his toll-book, and in the paſs-ticket or permit, the number of tons and quarters for which tonnage is to be paid to the company. On a great number of canals the practice is different; the gauging-maſter prepares four ſlips of copper or lead, about $\frac{3}{4}$ of an inch broad, and $\frac{1}{8}$ thick, and ſtamps thereon at every diviſion anſwering to two tons, agreeable to the obſervations entered in his book, and between theſe ſtrokes are drawn to mark the intermediate tons and quarters of a ton. Theſe plates he ſees carefully nailed on to the ſides of the barge, under the number-plate; by help of which the toll-clerk, and the bargeman alſo, can at any time ſee the tonnage on board, by the place on the plates cut by the water's ſurface.

Moſt acts contain a proviſion reſpecting barges occaſionally navigating a canal, or any others where reaſon appears to the toll-clerk to ſuſpect a deception or fraud, for requiring the bargeman to give an accurate account of his lading on board; which if unſatisfactory, the toll-clerk may take ſuch barge to the neareſt wharf where accurate ſcales, ſteel-yards, or engines for weighing goods are kept, and there have the cargo unloaded and weighed; which expence, as well as a penalty, the bargeman is made to pay, if he had refuſed or neglected to give an account of his lading, or if his account ſo given ſhall prove below the real weight of the goods. New barges are uſually indulged, in two or three voyages, before they are gauged, in order the better to ſuit the bargeman's and gauging-maſter's convenience for doing it, during which they are ſubject to have their goods weighed, as they alſo are, whenever they have different goods on board, liable to different rates of tonnage, and do not give a ſatisfactory account of the weight of each.

In many acts there are clauſes inſerted to prohibit the planting of trees in the canal-hedges, or on its banks, as there are alſo in others, for reſtraining the company from erecting any houſes or buildings on the banks of the canal, except certain ſpecified public wharfs, unleſs for the immediate uſe of the canal. A clauſe will be neceſſary, to puniſh perſons who are found throwing ballaſt or any kind of ſoil overboard or into the canal, by which it might be choaked up: it will alſo be requiſite, ſtrictly to prohibit the throwing of looſe ſtuff, as chalk, gravel, ſand, &c. by means of ſhovels, from heaps or barrows on the bank, into any barge, unleſs a broad and cloſe ſtage of boards was firſt laid to catch the ſtuff, which will unavoidably ſcatter, and to prevent its falling into the canal.

Neceſſary tackle ſhould be kept in readineſs, for weighing up ſuch barges that are ſunk, without delay, on account of the total interruption that ſuch will often occaſion to the navigation. Where a ſunk barge lies ſo that another barge cannot be floated on each ſide of it, the following method may be adopted: chains ſhould be looped round the ſunk barge and hooked, having four ends of ſufficient length proceeding from near the four corners of the barge, two empty barges ſhould be brought, one to each ſide of the ſunk one, and ſtrong beams of timber be laid acroſs each of theſe barges, and the ſpace between them; water ſhould then be admitted into each of the barges by their plugs, to ſink them almoſt to the water's ſurface, the plugs ſhould then be put in, and the four chains be faſtened tight to the croſs beams, when a pump ſhould be uſed in each of the barges to throw out the water, and as this is accompliſhed, if the chains are properly fixed, the barge will be buoyed up, often to the ſurface of the water, ſo that ſhe may be freed by pumping her; if not, ſhe muſt be ſhoved along, ſuſpended between the light barges, to ſome ſtrong crane, where ſhe can be further aſſiſted, or into ſome dock or ſhallower place, where ſhe can be relieved by a repetition of the ſame proceſs.

Several further *Regulations for working of Canals* require yet to be mentioned: They are ſuch as relate to the penalties that ſhould be provided in the act or by-laws for preventing bargemen from taking in above a certain weight, adapted to the ſize of their boat and the depth of the canal; and alſo for preventing ſuch boats from damaging the lock-ſils or bottom of the canal, or ſticking faſt to the interruption of other boats. The nature of the lading and the manner of diſpoſing it in the boat, ſo that the ſides of the bridges, &c. may not be injured, ſhould be duly attended to. Penalties ſhould be provided to puniſh thoſe bargemen who ſuffer their boats to ſtrike againſt any of the locks or bridges, or thoſe who ſuffer their barge to lie either for unloading or any other purpoſe, ſo as to obſtruct the paſſage of other boats. In ſome acts this penalty is fixed, by the hours that ſuch interruption continues, and at an increaſing rate. Boats left at wharfs or other places, on or by the line of the canal, ſhould be moored at both their ends. Bargemen ſhould be prohibited from fiſhing, or having tackle for ſuch purpoſe on board. It ſhould be provided, and made known by the by-laws, that barges or veſſels going one particular way on the line, and on each of the branches, ſhould give way for thoſe they meet or have occaſion to paſs; and on narrow canals or branches, it ſhould be provided, that when two barges that are meeting each other firſt come in ſight, or one of them hails the other, that which is neareſt to a paſſing place, ſhall ſtop at or go back to the ſame to let the other paſs. Common trading barges and veſſels, and all others, ſhould be prohibited from paſſing any locks or moving along the canal except in the day-time, and for this purpoſe it is uſual to divide the months of the year into three or four portions, and to ſpecify the hour both morning and evening in each, between which the canal is to be open. Light boats, for the conveyance of market-goods, parcels, &c. are allowed on ſome canals, as the *Grand Junction*, to paſs on during the night, their owner paying a ſpecified ſum for a licence for ſuch privilege, engaging to employ the moſt careful and experienced boat-men, and to make good all damage which ſuch boats may do to the works of the canal, or to the barges or property of other traders. Mr. *Thomas Pickford*, the great waggon proprietor, has ſubſtituted boats in place of many of his waggons, and which travel night and day, and arrive in London with as much punctuality from the midland and ſome of the moſt diſtant parts of the kingdom, as the waggons do.

As few of the tunnels are conſtructed wide enough for two wide barges to paſs each other therein, it may become neceſſary in ſuch caſes, where the tunnels are long, to eſtabliſh an overſeer at each end of the tunnel, where a baſon of ſufficient dimenſions for ſeveral boats to lie and paſs ſhould be provided, to ſuffer no barges to enter at either end for an hour, or other period, or until the laſt boat from the other end is come out, to prevent wide ones meeting others in the tunnel. If the number of wide boats be very ſmall in proportion to the narrow ones, the periods for the entry of narrow boats may be ofteneſt repeated, and wide boats might, in extreme caſes, be only ſuffered to paſs the tunnel between the two baſons after dark in the evening, when the other boats are lying ſtill on the canal.

Gentlemen's pleasure-boats, and narrow short husbandry-boats, for the use of the occupiers of the lands on each pound, are often allowed at very easy rates, if not quite free of tolls; and sometimes such, as well as any other boats laden with manures and road-materials, are allowed to pass the locks on the same conditions, at such times only as the water runs over the lock-weirs, or is within a very small quantity, as half an inch, of that height.

The regulations of vessels *passing the Locks* are usually very explicit in canal-acts, that boatmen may not suffer the water to remain in the locks longer than is necessary for their boats to pass; that every boatman in going down a canal, shall, previous to his bringing his boat into any lock, shut the lower gates of such lock and the cloughs thereto belonging, before he shall draw the cloughs of the upper gates; and, after he shall have brought such boat through the lock, he shall then shut the upper gates before he shall draw the cloughs of the lower gates, and in going up the canal, such boatman, as soon as he shall have passed his boat through the lock, shall shut the upper gates of the same, before he shall draw the cloughs of the lower gates, unless there shall then be a boat coming down the canal, in sight of the said boatman, in which case the lower gates of the lock shall be left shut, and the upper gates shall be left open; and in all dry seasons, or where there shall be a scarcity of water in the canal, the boat so going up (if within sight of a boat so coming down,) and at a distance not exceeding two hundred yards below a lock, shall pass through such lock before the boat coming down, and then such other boat shall come down into the lock; and if there shall be more boats than one, below and above any lock at the same time, in any such dry season, within the distance aforesaid (which distance shall be distinguished by a post set up for that purpose), such boats shall go up and come down at such lock *by turns*, until all the boats have passed, by which means one lock full of water may serve two boats. A penalty should be provided against any bargeman or other person, who draws the cloughs, except while barges are passing as above, or for leaving any clough open; as also against any lock-keeper or other servant of the company who gives undue preference to any boatman in passing the locks, or in unloading his barge at the public wharfs. Posts should also be provided by the side of the locks, for strapping or stopping the velocity of boats before they enter the locks, and penalties ought to be provided against the winding of their rope or strap round any part of the gates or lock, in order to stop a barge, except the strapping-posts before mentioned; after all, the engineer should be careful to form the heads of the gates, and all other projecting points about his locks, of such a sloping or wedge-like form, that the rope would have no hold upon them, but slip off. A clause should always be inserted in the act, for making master boatmen answerable for all damage done by their servants, giving them, however, the right of recovering from their servants in all cases of wilful damage or neglect. On some canals it is usual, for the masters to hire their men by the ton of goods which they navigate certain distances, instead of paying them by the day for their time.

For some time past, the rate of *Freight* on some canals, over and above the company's tonnage, has been two-pence per ton per mile, for unperishable goods, three-pence per ton per mile for perishable goods, and four-pence halfpenny for bulk goods. In times of distressing scarcity, like those of 1795 and 1800, the committees of several canals, have permitted the passage of imported grain, going towards the interior of the country, toll free, with the laudable intention of lowering its price to the community.

The *Principles of constructing River Navigations* require some further notice in this place, in addition to the particulars which we have already had occasion to notice respecting them in this article.

Mr. *Thomas Telford* has given an account of the navigation of the river *Severn*, which is printed in *J. Plymley's Agricultural Report of Shropshire*, pages 284 and 317, from which we shall collect some particulars, and remark thereon, with the view of shewing by an example, what are the nature and extent of the difficulties which navigation has to contend with, upon natural rivers. This justly famous river is navigable up to Welchpool, a distance of 155 miles by water, from the mouth of the Bath *Avon* river; the extreme branch of this river may be traced for about 45 miles above Welchpool, to Plinlimmon Hill, and numerous other branches extend for great distances into the country on both sides; the whole of this great length of river navigation was till lately unimproved by art, it having no locks, weirs, or other erections throughout its whole length for surmounting the numerous shallows and irregularities, which the current over variable *strata* had formed in its bed. The first, or lowest 42 miles of this river, extending to the city of Gloucester, are very wide for great part of the way, and have a most rapid tide; but the last 28 miles are so crooked, that ships are said to be often several days in passing it; on which account, a grand canal, calculated for vessels of 300 tons burthen, was in the year 1793 projected and begun, between *Gloucester and Berkley*, of 18¼ miles in length, for avoiding these 28 miles of the river. From Gloucester to Worcester the distance is 30 miles by the course of the stream, the rise in this length being 10 feet, or at the rate of 4 inches in a mile: from Worcester to Stourport the distance by water is 13 miles and the rise 23 feet, or at the rate of 1 foot 9 inches per mile: from Stourport to Bridgenorth it is 18 miles, and the rise 41¾ feet, or 2 feet 4 inches per mile on the average; and, from Bridgenorth to the New Town at the junction of the *Shropshire* canal, called *Coal-port*, the distance is about 7 miles, and the rise about 19 feet, being a rate of about 2 feet 8 inches per mile. It was, we believe, that excellent and public-spirited individual, Mr. *William Reynolds*, the founder of *Coal-port*, who caused an account to be daily registered, of the depth of the stream in the bed of the *Severn* river at that place, between the 7th of October 1789, and the 23d of December 1800, of which Mr. *Telford* has given us the particulars, except on 12 occasions when the river had overflown its bounds and covered the usual marks, on Sundays during some part of the time, the intervals of frost in which the river was frozen over, and for three short intervals, when unfortunately the experiment was by some accident suspended. These valuable materials we have examined with considerable care, and shall present our readers with some results therefrom, that will be of use in judging of the interruptions from floods, drought, and frost, to which river navigations are liable; and we do not apprehend that this river is more subject to them than the British rivers are in general, excepting those smaller ones like the Colne, the Wandle, and others, which are supplied principally by spring-waters. During all the months of *January*, in the above period of 11 years, ending the 6th of October, 1800, the river was twice overflown, (2d Jan. 1790, and 27th Jan. 1800,) and exceeded, we should suppose, the depth of 16 feet, that being the greatest depth at any time recorded; and several times, when no depths are inserted to the great floods, it is stated in the table that the water was above all the marks: besides these, there were 32 smaller floods, or times when the water had risen, and was falling again for some days after; the highest of these had a depth

depth of 13 feet (5 Jan. 1790,) the loweſt 4 feet, and the mean of the whole of theſe floods is $7\frac{1}{2}$ feet. In the months of *February*, there were two of theſe overflowings, one of which (11 Feb. 1795,) followed a froſt, and continued for 5 ſucceſſive days: 19 floods, the two higheſt of which were equal (17th and 20th Feb. 1799,) to 12 feet; the loweſt that we have noticed was 4 feet, and the mean depth of water in all of them was $7\frac{3}{4}$ feet nearly. In the months of *March*, the bounds were but once overflown, and we have noticed 11 other floods, the greateſt height being 9 feet, (17th March 1794,) at which it continued 3 days, and the loweſt $4\frac{1}{3}$ feet, and the mean height of them about $6\frac{1}{2}$ feet. During the months of *April*, two overflowings of the river are mentioned, the heights of 14 floods are recorded, the higheſt (5th April 1794,) 10 feet, the loweſt $4\frac{1}{3}$ feet, and the mean $6\frac{1}{2}$ feet. In the months of *May*, but one overflow of the river is mentioned, (30th May 1792,) and 7 floods, the greateſt depth of water at thoſe times being $7\frac{3}{4}$ feet, (6th May 1797,) the leaſt $4\frac{1}{12}$ feet, and mean $5\frac{1}{2}$ feet. The months of *June* produced no overflowings, but 8 floods are recorded, the greateſt $6\frac{1}{2}$ feet deep, (4th June 1797,) the leaſt $3\frac{1}{6}$ feet, the mean height of them being $5\frac{1}{4}$ feet. The months of *July* produced no floods which overflowed the banks or marks; of the 10 that are recorded, the higheſt was 7 feet, (1ſt July 1797,) the leaſt $3\frac{1}{6}$, and the mean of them $4\frac{1}{2}$ feet. During the months of *Auguſt*, the higheſt of the 19 floods, or higheſt waters that are mentioned, was 11 feet, (19th Aug. 1799,) the leaſt that we have noticed is 3 feet, and the mean height was $5\frac{1}{4}$ feet. The months of *September* produced 17 floods, the greateſt $9\frac{1}{2}$ feet, (23d Sept. 1797,) the leaſt $3\frac{3}{4}$, and the mean we find to be 6 feet nearly. In the months of *October*, one overflow took place (10th Oct. 1789,) and 24 other riſes of the water or floods, the greateſt being 10 feet, (10th Oct. 1799,) the leaſt $4\frac{1}{2}$ feet, and the mean $6\frac{1}{2}$ feet. In the months of *November*, one overflow is mentioned, (1ſt Nov. 1792,) 28 other floods, the greateſt of 11 feet depth (8th Nov. 1799,) the leaſt $4\frac{5}{6}$ feet, and the mean $6\frac{1}{3}$ feet. Laſtly, in *December* in the ſeveral years, two overflows of four days each are recorded, (1ſt Dec. 1791, and 2d Dec. 1794,) the number of floods being 29, the greateſt height 16 feet (5th and 7th of Dec. 1797,) the leaſt 4 feet, and the mean we find to be $7\frac{1}{3}$ feet in height.

From the above it reſults, that the *Severn* river at Coalport is ſubject to about one overflowing of the banks annually, beſides about 20 leſſer floods, varying (in 11 years,) from 16 to 3 feet in height, the mean height of which is about 6 feet 7 inches. It alſo appears, that the greateſt floods, and thoſe occurring the ofteneſt, are in December and January; that the feweſt floods happen in May and June, and are the leaſt in height in June and July.

We have now to mention the reſults of an examination for the loweſt ſtates of the ſtream of water in the river, in the above period. In all the *Januaries* the depth never was leſs than 1 foot 8 inches, on one of the two ſuch occaſions (13 Jan. 1793,) it continued ſo for three days. In *February* it never was but once ſo low as 1 foot 8 inches, and then (26 Feb. 1797,) it continued ſo for three days. In the months of *March* we have noted ten loweſt ſtates of the water, four at 1 foot 8 inches, four at 1 foot 6 inches, and two at 1 foot 5 inches (19 and 25 March, 1797,) the mean of theſe low-waters being 1 foot $6\frac{1}{4}$ inches. In the months of *April*, ten low-waters were obſerved, the greateſt 1 foot 8 inches, and leaſt 1 foot 2 inches (30 April, 1796,) the mean being 1 foot 5 inches nearly. During the months of *May*, eighteen low-waters occurred, the greateſt being 1 foot 8 inches, and leaſt 1 foot only, and which continued for ſeven ſucceſſive days (29 May to 4 June, 1795,) the mean being 1 foot $5\frac{1}{4}$ inches. In the months of *June* we notice twenty-three loweſt ſtates of the water, varying from 1 foot 7 inches to 1 foot, which laſt was the depth at four different periods, (two of which amounting to twelve days were in June 1791,) the mean of theſe is 1 foot $3\frac{1}{2}$ inches nearly. In the months of *July* the low-waters were thirty-one in number, varying from 1 foot 8 inches to 11 inches, (14 and 15 July, 1794,) the mean 1 foot $3\frac{1}{4}$ inches. In the months of *Auguſt* there appear to be thirty-three low ſtates of the ſtream, the higheſt that we have noticed are 1 foot 8 inches each, and the loweſt only 9 inches! (5 and 16 Auguſt, 1800,) the mean 1 foot 4 inches. During the months of *September* the low-waters were twenty-four in number, the greateſt 1 foot 8 inches, and leaſt 11 inches, (7 September, 1796,) the mean being 1 foot 4 inches. In *October*, in the different years, were twelve low-waters, from 1 foot 9 inches to 1 foot 1 inch in height, (3 and 4 October, 1791,) mean 1 foot 6 inches. *November* produced only three low ſtates of the water, 1 foot 10 inches and 1 foot 8 inches, (8 November, 1791, and 11 November, 1796,) mean 1 foot 9 inches. Laſtly, in the months of *December* four low-waters are recorded, 1 foot 9 inches, and 1 foot 7 inches, (9 December, 1793, and 20 December, 1799,) the former continuing for three days,) the mean of theſe being 1 foot 8 inches.

From the above it appears, that the *Severn* at this place is ſubject to between fifteen and ſixteen low ſtates of the water annually, and each of them will be found of much longer continuance than the floods are; the loweſt having 9 *inches only* in depth of water, the greateſt that we have here taken out being 1 foot 10 inches, and the mean of all ſuch we find to be 1 foot $4\frac{3}{4}$ inches. It alſo appears, that it is not oftener than once in two or three years on the average, that a low ſtate of the water (1 foot 8 inches) occurs in any of the four winter months, November, December, January, and February; that June and July are ſubject to the loweſt waters, and July and Auguſt to the moſt frequent riſes of the water; the reaſon of this laſt circumſtance appears to be, that in this low ſtate of the water, and when the breadth of the river is the leaſt, the effect of almoſt every partial thunder, or other heavy ſhower, on any of the branches of this river, is viſible in the ſame at Coal-port, which waters could not have been noticed, when the ſtream was ſo many times larger, as it generally is. We obſerve, that the mean height of the low-waters in both Auguſt and September is 1 foot 4 inches, (the general mean of all the months being 1 foot $4\frac{3}{4}$ inches,) and if the mean of the ſix ſummer months, from April to September incluſive, be taken, it will be found almoſt exactly 1 foot 4 inches: what is alſo remarkable, the river has been found to be far more ſtationary at this particular height than any other, ſince, on thirty-five days, beginning with the 25th May, 1793, it never varied from that height, on eleven days, beginning 15 June, 1795, and on ten days, beginning 15 July, 1795, it alſo ran ſteadily at that depth; while it never remained but twice at any other height for ten days together, viz. fifteen days, beginning 23 September, 1795, at 1 foot 2 inches; and ten days, beginning the 14 Auguſt, 1795, at 1 foot 3 inches depth: but twenty-ſix inſtances occur in all the eleven years, of the water remaining for more than four days together at any other height than 1 foot 4 inches, ſeveral of theſe being very near that height; and, indeed, inſtances of a ſtable height are ſo rare, that often for months together no two following days are to be found alike. From the above we may, we think, with tolerable ſafety infer, that 1 foot 4 inches is the depth of the ſtream of water in the *Severn*, at *Coal-port*, 45 miles, below the upper end, and 110 miles

above the lower end of its navigation, arifing *from fprings;* the height of water above this being principally occafioned by the rain, which fo frequently falls in one part or other of the Welfh mountains and hilly tracts, whofe running waters this river receives. Seven times in the above eleven years the *Severn* was frozen over at Coal-port; on one of thefe occafions the river continued locked up for 29 days, beginning the 11th January, 1795, the next longeft interruption, from the river being frozen over, was nineteen days, after 27th January, 1798; fourteen days, after 1ft February, 1799; fourteen days, after 20th December, 1799; thirteen days, after 2d December, 1796; eight days, after 22d December, 1796; and, laftly, three days, after 2d January, 1795. Thefe amount in all to 100 days, or to about nine days of total interruption from ice annually, fuppofing they had happened regularly; but it appears above, that in only four of the winters in this period was the Severn froze over at *Coal-port*, viz. in that of 1794-5, for thirty-two days; that of 1796-7, for twenty-one; in that of 1798-9, for thirty-three days; and, in that of 1799-1800, for fourteen days; or, for twenty-five days on the average, in each frofty winter, while feven winters paffed without fuch interruption. The water was generally low (in one inftance only 1 foot 7 inches,) when the *Severn* became froze over as above, occafioned, we apprehend, principally by the rapid and great evaporation which will be found always to precede and accompany a froft; and by the froft having fet in and retarded the fall of the waters, in the open and expofed parts of the country which fupplies the *Severn*, before the fame was become intenfe enough to cover that river with ice, in fo deep and narrow a vale as at Coal-port.

Mr. *Thomas Telford* remarks, that the year 1796 afforded fo ftriking an inftance of the fluctuating nature of this river, that during the whole of that year, there were not two months in which barges could be navigated, even down the river, with a freight which was equal to defray the expences of working them; an interruption to trade that was feverely felt by the great coal-mafters and manufacturers of iron in thofe parts, in particular. The fame intelligent engineer obferves, when fpeaking of the *Severn*, "the inconveniences arifing from the irregularities of the water have always exifted in fome degree, but they have been greatly increafed by the embankments which have lately been raifed to protect the low lands in Montgomeryfhire, and in the upper parts of the county of Salop. Formerly, when the river had arrived at a moderate height it overflowed thefe lands to a great extent, which thereby operated as a fide refervoir, and took off the top waters of the high floods; and thefe waters returning to the bed of the river by flow degrees proved a fupply for the navigation, for a long time after the flood began to fubfide, but being now confined to a narrow channel, they rife fuddenly to a great height, and flow off with more rapidity than formerly; whereby the navigation is at one period impeded by uncontroulable floods, and at another left deftitute of a fufficient fupply for its ordinary purpofes." Befides the embanking of low lands by the fides of confiderable rivers noticed above, another caufe has been obferved by us, for the change for the worfe, which is well known to have happened to many of our navigable rivers, within the laft 50 years; in which period, a great portion of the common-field parifhes in England have been inclofed, and in the greater number of inftances, new and ftraight brooks and water-courfes have been cut therein, inftead of the exceedingly crooked and ferpentine courfes which moft of them had; thefe have had the effect of letting down the rain waters much more freely than formerly, from almoft every branch of many of our eaftern and fome other rivers, and have occafioned floods much more fudden and high than were probably ever before experienced; at Bedford, on the *Oufe*, we remember reading of two or three immenfe floods, within a few years paft; fuch as would have effectually prevented the erection and growth of the fouth part of the town on its prefent fite, if fuch floods had ever before prevailed: and the effects of thefe increafed floods have been experienced in the fens, through which thefe rivers pafs, by the continual neceffity which has been found of raifing their banks to prevent the water overflowing them, and filling the adjacent country. In the fens this remedy has been found adequate; and the evil might have been remedied higher up the fame rivers, if attention had been paid to increafing the water-way under their bridges, erecting others in place of the numerous fords that on fome rivers exift, and cutting off fudden bends in the courfe of the rivers; and above all, requiring the mill-owners to make more capacious flood-gates, to be opened on the firft rife of water, in order that it may pafs off by the channel, to prevent the valley being filled for a great diftance above, and agriculture being interrupted or prevented, as it ufed to be in the fmaller vallies above, before the brooks therein were ftraightened, or new ones cut. The fame caufes which have occafioned this increafe in the rapidity and height of the floods, have, as obferved by Mr. *Telford*, caufed the quantity of water to be lefs in the rivers in the general; a circumftance which receives ftrong confirmation from an able pamphlet, faid to be written by the late Mr. *Wedgewood*, in 1765, entitled "A View of the Advantages of Inland Navigation," wherein it is mentioned, fpeaking of the *Severn* river near to Coal-port, "that the loweft water that ever happens, in the drieft fummer, is *never lefs than* 18 *inches*, which is fufficient to carry veffels of 16 or 17 tons burthen at any time." We have feen above, that this river, fince 1789, often runs with a ftream no more than 16 inches deep for confiderable periods together, and is frequently fo low as not to have a foot depth of water in it, while inftances of fuch extreme drought have been recorded, that the depth was reduced to 9 inches, or half what was formerly faid to be its loweft ftate. The progrefs of agricultural improvements in the laft age would have had a ftill more fenfible effect, in producing a low ftate of the water in our rivers, after the fudden floods are run off, but for another, and contrary effect from the above, by which they are accompanied; we allude to the more general drainage and cultivation of the furface of the ground, by which it is enabled to abforb and take in fo much greater a portion of every fhower of rain than formerly, moft of which water afterwards finds its way through land. or permanent fprings, to the brooks and rivers, and prevents that very diminifhed ftate of them, which every dry feafon muft now otherwife occafion. We may confider, that all land whofe furface is wet, and in want of draining, is in that ftate as incapable of abforbing or retaining the rain waters, as the tiles of the roofs of houfes, or the paved ftreets in a town are; and, that when that moft effential of agricultural improvements, under-draining, has been applied, and the furface rendered fit for cultivation, that the whole of a large portion of the fhowers of rain, and a confiderable portion of all of them, are abforbed and retained in the land, to be afterwards flowly given out, by the under-drains or fprings, for equalizing the rivers. We were not fully aware of the great effects which a change to cultivation from a ftate of neglected common, has upon the abforbent powers of the foil, until viewing the improvements of the late excellent *Duke of Bedford*, in Crawley, in Bedfordfhire, before mentioned.

In projected improvements upon any of our old river-navi-

gations; or in extending the navigation thereon above the tide-way, it is of importance to examine the ſtate of the whole country, to which the river in queſtion acts as a drain, to obſerve accurately whether cultivation, or the breaking up of lands, and the practice of draining have been going on, or are likely to be ſo in any conſiderable degree, within a reaſonable period; as alſo to obſerve particularly the ſtate and extent of the valleys and meadows, over which the waters are or have been ſpread in ordinary floods, and the probability of ſuch being further prevented by ſtraightening or enlarging the beds of the brooks and rivers, or embanking the courſes of the ſtreams; theſe, with the moſt correct information that can be obtained from different millers and others, who live on the banks of the river, or from ſcientific individuals, who have cauſed accounts to be kept of the height of the water, will be neceſſary data for determining the magnitude and nature of the works which will be neceſſary on the propoſed navigation.

Mr. *William Chapman*, in his *Obſervations*, often before quoted, *page* 74, when treating of the canals of China, which are in effect but new channels for a part of the ſtreams of their rivers, takes occaſion to introduce ſome uſeful obſervations on the crookedneſs and unequal ſections of rivers, and on the effects of ſhallows, weeds, and other impediments, upon the velocity and height of the ſtream, that we muſt reluctantly for the preſent paſs over, referring the reader to our article River. As an inſtance of the fall and velocity of large natural rivers we are told, that the Ganges for 60 miles, having the mean width of 3-4ths of a mile, and depth of 15 to 20 feet, was found to have a fall, in a direct line, through the immenſe flats and rice-fields on its ſide, of 9 inches in a mile, but by following all the bends of the river's courſe, the fall was reduced to 4 inches per mile, and its velocity therein did not exceed 3 miles per hour. On aſcertaining readily the velocity of ſtreams of water, and comparing the ſame with theory, ſee *Nicholſon's Journal*, 8vo. vol. iii. p. 32 and 87.

Mr. *William Chapman* ſeems to incline to the opinion, that locks may not always be eligible on river-navigations, and ſays (p. 87,) that "during the flooded ſtate of rivers, all ſmall falls are equalized, as they neceſſarily riſe higher below than above a rapid; therefore I am far from ſaying, that running canals with a ſmall fall are not, in many inſtances, eligible on the ſhores of great rivers; and that well deviſed ſtops, eaſily opened and cloſed, (not ſuch as lift up like thoſe deſcribed in China, nor open againſt the ſtream as gates,) are not ſometimes preferable, to incurring the charge of locks. In other nearly ſimilar inſtances where locks are eligible, their piers and gates alone, will be ſufficient without any other floor or ſide walls, than a concave and battered pavement, continued through the bottom and up the ſides of the ſpace between the piers. The eligibility, and the particular conſtruction of theſe works, will much depend on the nature and extent of the beds of the rivers, the difference between their low and flooded ſtates, the height and alſo the permanency of their ſhores, and the quantity of floating ice.

The greater number of rivers through which new navigations are now required to paſs, will be found occupied by mills, at ſhorter or longer diſtances from each other, according to the fall of the water in moſt inſtances; at the tail of moſt of ſuch mills, will be found a large and deep pool, which the fall of water from the mill-courſes and flood gates has torn and excavated, and a ſhort diſtance below this pool a ſhoal or bed of gravel, or other matters, will in general be found, that would prove ſo expenſive to remove, and would in general be ſo ſubject to accumulate again by a further excavation of the pool from the increaſed fall of the water into it, that it will in general be the cheapeſt and moſt effectual way to begin a new cut for the navigation below this ſhoal, and continue the ſame up by the ſide of the pool to the bank of the mill, wherein a pound lock muſt be conſtructed, either of timber or maſonry, for gaining the aſcent to the mill-dam or upper pound. In rapid rivers ſubject to great floods, the utmoſt care and attention of the engineer to the conſtruction of ſuch works will be neceſſary, to prevent their being demoliſhed by the firſt flood perhaps after their erection. Where mills do not intervene, and rapid and of courſe ſhallow places occur in the bed of the river which is to be made navigable, a ſide-cut muſt be begun from above ſuch ſhallow, and if practicable at the beginning of a conſiderable bend of the river which the ſide-cut may cut off and ſhorten; in continuing this ſide-cut downwards towards the place where the lock is to be placed, and the junction below the ſame is to be formed with the river below the ſhallow, care muſt be taken to conduct the ſide-cut, which is to be upon a level as far as the lock, as ſoon as poſſible acroſs the flat meadows to the borders of the high ground, along which it ſhould ſkirt, to the place of the lock, if this is practicable, on account of the width of the meadows; otherwiſe a counter-drain or parallel cut muſt be taken up from below the lock, as far as is neceſſary, on the land ſide of the ſide-cut, to drain off the water, and prevent a ſwamp or pond being formed above the lock and between the ſide-cut and the high ground, as is almoſt invariably done by the ancient mill dams on moſt rivers and ſtreams: it is, however, with the utmoſt care and precautions that the counter-drain ſhould be adopted, otherwiſe, in time of floods, when the meadows are overflowed, ſuch a current would ruſh into and down the declivity of the counter-drain as to endanger the tearing thereof, and of the bottom and ſides of the cut or bed of the river, into which it vented below the lock. We have ſeen large and expenſive ſluices erected upon and near to the vent of counter-drains circumſtanced as above, of greater height than the top of the floods, which were found neceſſary to be built, and kept ſhut on the approach of a flood to prevent the action of the counter-drain, until the flood had ſubſided ſo far as not to overflow the meadows adjoining the counter-drain. Acroſs the bed of the river at the moſt convenient place below and near the upper end of the ſide-cut, an opening-weir muſt be conſtructed, by which the water in the river can always be kept at a proper height for covering the ſhallows and bed of the river to a proper depth for the navigation; ſeveral of theſe opening-weirs have within theſe few years been conſtructed on the *Thames*, one of which near Windſor has been deſcribed and drawn by Mr. *Zach. Allnutt* in his *Conſiderations on the beſt Mode of improving the River Thames*, 1805, p. 22. It conſiſts of ſeveral ſtrong piles or poſts driven firmly into the bed of the river at 20 to 25 feet apart, in a ſtraight line acroſs the river: the intervals between theſe piles are driven and nicely filled up with pug-piles, or dovetail piles, as before deſcribed in this article; theſe laſt are afterwards ſawed off ſtraight and even with the bottom of the river, and have a ſtrong and ſound ſill nicely fitted and ſpiked on to them, and into each of the large piles at its end; by this means the water is prevented from ſoaking or making its way, except through the rectangular openings between the ſeveral piles, which ſhould be at leaſt as high as the higheſt floods, and have their tops connected by ſtrong croſs pieces of timber bolted on to them; in theſe croſs pieces, and in the ſill below, a number of holes are prepared for placing at equal intervals as many upright pieces of wood, called rimers, with rebates in their ſides,

for temporary gates to ſlide down in, and reſt againſt; after theſe rimers are put in, a ſluice or gate, with a tall handle to reſt againſt the upper, or croſs piece, is put in between each rimer; and, above theſe, another ſet of gates, called overfalls, with ſimilar handles, are fitted, to be occaſionally uſed in dry ſeaſons, when none of the water is to be ſuffered to eſcape, except by the ſide-cut and lock-paddles. In time of floods, all theſe gates, overfalls, and rimers, are taken away, by perſons who go in a boat for that purpoſe; which operation, we are told, can be performed in three hours, and the water is ſuffered to take its free courſe through the openings: as the water ſubſides, a few of theſe gates are put in at a time, leaving the water its courſe through the others, until all of them are in, when on any ſmall riſe of the water, the ſame falls over the tops of theſe gates into the bed of the river below; when a greater depth of water is wanted above, the overfalls or upper gates are ſucceſſively put in upon the others; theſe laſt being of ſuch a height that the water can fall over their tops before it would overflow the meadows in caſe of its riſing, and the men not attending or being expeditious enough in taking away the overfalls, and then the gates, if the progreſſive riſe of the river ſhould render it neceſſary. Mr. *J. Plymley* in his report before quoted, page 316, has given a plate of a weir of this ſort for a river, which is called a gate ſluice, with 17 gates, but we have looked in vain for any deſcription or account thereof in his volume. In the *Thames* and ſeveral other rivers, *Jetties*, or *Weir-hedges* have formerly been made, for diminiſhing the width of the river below the ſeveral ſhoals, in order to make a deeper but narrower and more rapid current over the ſame, as is done, we are told, on the China canals; but the rapid and dangerous currents which theſe and the under-water weirs occaſion, particularly in high water times, have been ſo juſtly and loudly complained of, that we truſt the ſame will, ere long, give place to the ſide-cuts, pound-locks, and opening-weirs, above deſcribed. The principles on which jetties are made to raiſe the water in rivers, and the mode of calculating their effects may be found in *Nicholſon's Journal*, 8vo. vol. iii. p. 35.

For improving the navigation of rapid, confined, and variable rivers, like the *Severn*, Mr. *Thomas Telford*, in *Plymley's Report*, p. 287, has recommended the deepening of the lower part of the bed of the river in the ſhallow places, in order to equalize the declivity and current of the river: a very experienced engineer has ſuggeſted, that deepened ſhallows, without jetties or ſimilar conſtructions, would ſoon be again filled up in many caſes. In the higher parts, Mr. *T.* propoſes to erect ſolid and durable weirs of maſonry acroſs the river upon the ſhallow places, with ſide-cuts and pound-locks by the ſide of them, for the navigation; and the river when thus diverted, may, as he juſtly obſerves, be applied to many important purpoſes of machinery, and for irrigating of the meadows, which would thus be brought within its reach. There is no doubt but this method is practicable, and would ultimately anſwer well; but the expence would be very great of erecting ſubſtantial weirs, and making the banks of the ſide-cuts, and walls, and gates of the locks, high enough to prevent the floods from breaking over into them, a condition which ſeems neceſſary, if barges are to be able to proceed at all times; the towing-path ſhould alſo for the ſame purpoſe be made up with a regular ſloping bank next the river, preſenting no inequalities or projecting objects to catch or wear the towing-lines, ſo that its top or path ſhall be always above water. On a river which riſes 16 or 17 feet or more, theſe works would be attended with a moſt ſerious expence and difficulty, particularly where cliffs riſe almoſt perpendi- a ſtream, unleſs great expence indeed was incurred to obviate it, would be ſubject to have its work interrupted by every large flood: the working of barges on a river with ſuch cuts, locks, and towing-paths, as we have mentioned, would be attended with conſiderable difficulties; tall maſts muſt be uſed for attaching the towing-line in dry-times to bring the line on a level, or nearly with the horſes, and in floods it muſt be fixed lower down, or to a ſhorter maſt: and, in ſuch caſes, the utmoſt care might not always be able, where the works are neceſſarily confined by rocky banks, to prevent barges from ſometimes miſſing the entrance of the ſide-cut, and being precipitated down the current over the weir, and being ſunk. A towing-path, locks and banks of a leſs height, ſo that the floods would frequently cover them, beſides their being totally uſeleſs in ſuch times, would be liable to be damaged and waſhed away, (unleſs conſtructed in the moſt careful and expenſive manner,) and the cuts and locks to be filled up in a great meaſure by ſand, or gravel, in rapid rivers. Mr. *William Reynolds* ſet an example which has ſince been followed, on a great length of the *Severn's* bank, of conſtructing a towing path for horſes, inſtead of the devious way over projecting rocks, looſe ſands, mud, and every other obſtacle which the men who uſed, from time immemorial, to perform the ſlave-like office of hauling the barges along, were obliged to travel: we are not acquainted with the height of theſe new towing-paths, or whether they are at times, and how frequently, covered and uſeleſs by reaſon of the floods. Mr. *Allnutt* informs us, that one horſe commonly tows a barge of 130 tons burthen down the *Thames* above Richmond, at the rate of two and an half miles per hour. While on the running canals of China, *ſir George Staunton* obſerved a boat of a light conſtruction, with only 14 tons lading, of eight feet width of floor, about 10 feet width of water-line, and 50 of extreme length, drawing two feet three inches of water, and ſharp at the ends, dragged againſt a ſtream whoſe velocity was $5\frac{1}{2}$ Engliſh miles per hour; and, although there were 28 trackers, or men hauling at the line faſtened to the boat, beſides three men in the boat poling it on, it advanced only at the rate of $\frac{1}{4}$ of a mile an hour; although the channel was not materially contracted in either width or depth of water-way, in proportion to the ſection of the boat. Mr. *Thomas Telford* has (p. 288.) propoſed another method of improving the *Severn* river, by collecting "the flood waters into reſervoirs, the principal ones to be formed among the hills in Montgomeryſhire, and the inferior ones in ſuch convenient places as might be found in the dingles, &c. along the banks of the river. By this means, the impetuoſity of the floods might be greatly leſſened, and a ſufficient quantity of water preſerved to regulate the navigation of the river in dry ſeaſons, and likewiſe to anſwer many other uſeful purpoſes, ſuch as the forming ponds for inland fiſheries, the ſupplying of artificial canals, and the watering of land. This, it is thought, might even prove the ſimpleſt and leaſt expenſive mode of regulating navigable rivers, eſpecially ſuch as are immediately on the borders of hilly countries." An engineer of the firſt reputation in his profeſſion (Mr. *Rennie*,) intimates, that after what has been ſaid reſpecting the exceſs of flood water in the river Roch above the ordinary ſupply, the idea of correcting the floods of the *Severn* by reſervoirs, muſt appear to be ridiculous. Mr. *William Jeſſop*, on another occaſion already referred to, ſays, that the rivers may be rendered nearly uniform throughout the year by reſervoirs.

The old clumſy ſtone or brick bridges upon rivers are a very principal interruption to the navigation thereon, by preventing the continuation of the towing-path in a place where it is generally the moſt wanted to ſurmount the rapid

bridge; the masts of vessels are also obliged to be struck. These circumstances recommend the more general imitation of the spirited individuals near Coalbrook-dale, who have there erected two cast iron bridges over the *Severn*, whose single and capacious arches remedy these evils. We have already spoken of them under the article Bridge, and in the present one, and therefore proceed to the only remaining subjects that at present occur to us, relating to the deepening of rivers: the *heaving of ballast*, or taking up of sand, gravel, or other loose or soft matters from the bottom of rivers, is usually performed by a strong pole, having a flat ring or hoop of iron fixed on its end, to which a strong leathern bag is fastened, like what is called a landing-net among fishermen; or for taking up gravel only, a fine and strong net is used instead of the leathern bag; the edge of this hoop is made sharp, so as to strike into the bottom, when a man pushes it down by its pole; near to this hoop a rope of considerable length is fastened, which is held by a man that stands at the head on the gunwale of a barge at anchor, while another man at the stern strikes the hoop and bag into the bottom, the man at the head then hauls at the rope to drag the bag along and scrape the bottom, while the other man shoves down the pole to which it is attached, until the bag is filled with sand, gravel, or other matters, which are wanted to be got up; the man with the rope then advances nearer to the other, and pulls up by the rope while the other does the same by the pole, and brings the bag over the side of the vessel, and empties its contents into the hold or room of the barge. If the bottom be hard, or the bag large, two or more men are employed to pull the rope, and sometimes a winch and roll on which the rope or chain winds, are used for dragging the hoop and bag along the bottom, and for hauling the same up to the surface, when the man at the pole finds that the bag is full, and begins to pull instead of push by the pole: this is the employment at Woolwich of a great number of convicts, instead of their being transported. Solid matters or rocks when they happen to want excavating, below the level that the water can be drawn off to, or the ebb of the tide, seem to require all the skill and resources of the engineer. Near to the entrance of the new *East India Docks*, in the way of ships in the river *Thames* at Blackwall, is a rock or large stone of exceedingly hard silecious pudding-stone, consisting, as we have been informed, of the hard small chert pebbles which abound so much near London, embedded in a cement still harder than themselves; detached blocks of which pudding-stone are by no means uncommon in the London *strata*; this rock is so hard that no tool is capable of boring it, and though for some years past the committee for improving the port of London have been occasionally advertising for persons who were willing to undertake or contract for removing the upper part of this rock, about 40 feet in length and 30 in breadth to the depth of about 18 feet, yet the rock still remains. The conduct of this business is now, it is said, committed to Mr. *Jessop*, an able engineer; and we hope soon to hear of this dangerous impediment being effectually removed.

Having now given the principles and practice of canal-making, and of river-navigations and rail-ways, as forming one great, compound, and connected *System of Inland Communication*, we now proceed to give a concise account of all the different establishments of this kind in the United Kingdoms. This part of the present article, although far short of the degree of perfection which we were desirous of giving it, has been attended with great labour, in research for the scattered, and often scanty materials, that are to be found respecting many of these undertakings, which will ever remain as stupendous monuments of British enterprize and spirited exertion.

Respecting the method of arrangement, we found it inexpedient to follow those who have attempted to give an account of some of these concerns, in the order of time in which they were projected or begun; because so many of them, in distant places, were projected at the same periods, while some were quickly begun and completed, and others remained a great while in hand.

The great length of some of these works or undertakings, the shortness of others, their various directions and their general and multiplied intersections with each other, rendered any geographical arrangement of them, as from north to south, or otherwise, equally difficult and improper. We trust, therefore, that our readers will approve of the plan which we have adopted, of giving the whole of these undertakings, rivers, canals, rail-ways, &c. in one alphabetical series, arranged according to the *incorporate, or parliamentary name* of each, where the same are under special acts of parliament. And, as many important lines of canal have been surveyed and described, but never since were executed, we have thought it right to preserve the memory of many of such, by giving them a place in the regular series, but printing their titles in Italics, to distinguish them from the works existing or now proceeding with, which will be printed in small capitals. Our principal aim has been to exhibit, as concisely as possible, the principal features of each concern, and to trace its connecting points with all the other adjoining ones; by the help of which, it is hoped that our readers may be able to trace out and comprehend this great and unparalleled system of improved inland communication, which has, and will continue to operate so powerfully towards our national prosperity.

Aberdare Canal. This undertaking was begun under an act of the 33d of Geo. III.; its general direction (beginning at its lowest end, as we shall always do in these descriptions) is about N.W.; it is $7\frac{1}{2}$ miles in length to Aberdare, besides an extension thence, in nearly the same direction, by a *rail-way* for $8\frac{1}{2}$ miles further; it is situate in the county of Glamorgan in South Wales, and is not far from the sea-coast, or very greatly elevated above the same. The great coal and iron mines, and works near Aberdare, Furno-Vaughan, &c. seem its principal objects. It begins in the *Glamorganshire* canal near Eglwysila, and terminates in the *Neath* canal at Abernant. The first $4\frac{1}{2}$ miles of the canal are level, and thence it rises 40 feet to Aberdare. Mr. *Thomas Dadford*, jun. is the engineer. A lock of sufficient height, with proper side-weirs, was made near the lower end, to prevent the *Glamorganshire* canal from suffering by floods, that may make their way into and through this canal. The company may raise 35,500l. shares, 100l. each. The rates of tonnage are too long for such an abridged account as this; they will be found in *Phillip's 4to. History of Inland Navigation, Appendix*, p. 38. Boats 12 feet long and 5 feet wide may be used, free of toll on the pounds, by the adjoining occupiers, for their husbandry purposes. At Aberdare works are some curious machines; one is said to be a pair of water-wheels, working one below the other like a figure of 8.

Aberdeenshire Canal. Acts 36 and 41 of Geo. III.—The general direction is about N.W. for 19 miles in length, in Aberdeen county in Scotland; it is near the sea-coast, and is not greatly elevated in any part; the principal objects seem the supply of the town Aberdeen, the exportation of granite stone from the famous quarries on its banks, and to form a communication between the harbour of Aberdeen and the vales of the river Don. It begins in the tide-way in the *Dee* river in Aberdeen harbour, and follows the course nearly of the Don river, in which it terminates at Inverury bridge; and passes the parishes of Old Machar, Newhills, Dyce, Kinnellar and Kintore.

tose. The rise is 170 feet by 17 locks; the width of the canal is 20 feet, and depth of water $3\frac{1}{2}$ feet. The harbour of Aberdeen, (connecting with the *Dee* river near its mouth, at the S. E. end of this canal), was surveyed many years ago by Mr. *John Smeaton*, and lately by Mr. *Thomas Telford*, who has, in his reports to parliament, recommended making it capable of receiving ships of 18 or 20 feet draught of water. It appears that this canal was completed and opened in June 1805. The company might by the first act raise 30,000l., shares 50l. each; and by the 2d act 20,000l. more might be raised on 20l. shares, bearing 5 per cent. interest. Half-mile stones to be erected. Pleasure-boats of twelve feet long, and four broad may be used on the pounds.

Adur River. The general direction of this river is nearly north for 12 miles in the county of Sussex: its objects are the import of coals, deals, &c., and the export of farming produce. New Shoreham and Steyning are considerable towns on or near it. It commences in the sea at Southwick below Shoreham harbour, and terminates at Bines-bridge in West-Grinsted. In September 1805, notices were given of the application for an act for extending this navigation from Binesbridge to Baybridge in Shipley.

Alford and Wainfleet. In July last (1805) a survey was ordered for an intended canal from Wainfleet haven to the town of Alford, the general direction of which line is nearly north, and about 12 or 13 miles in length, in the county of Lincoln: this line is near the coast, and seems but very little elevated above the sea: its principal objects seem the supply of Alford, and the export of husbandry produce: it is proposed to pass the town of Burgh. Wainfleet haven is said to be a very good harbour for trading ships.

Ancholme Navigation. Act 42 of Geo. III.—The general direction of this navigation is nearly south: it is almost straight (except the last four miles), and about 26 miles in length, in Lincolnshire. It is situate within 15 or 20 miles of the coast, and runs nearly parallel thereto through fens and level grounds for great part of its length. Its objects, besides a better drainage of these fens by a wide and straight cut, instead of the old course of the river Ancholme, seems the supply of Market-Raisin and of Caistor (by means of the *Caistor* canal, which joins it at South Kelsey), and the export of husbandry produce. It begins in the tide-way in the *Humber* river near Wintringham, and extends to the town of Market-Raisin, passing near the town of Brigg.

Andover Canal. Act about the 30th of Geo. III. Its general direction is nearly north, and pretty straight, following the course nearly of the *Anton* river (which is navigable to Rumsey) for $22\frac{1}{2}$ miles in length, in Hampshire; it is near the coast, and not very greatly elevated in any part above the level of the sea. Its general objects seem to supply fuel to the country, and to export its surplus of farming produce. It connects with the *Southampton and Salisbury* canal, the latter entering it at Red-bridge, and leaving it again at Kimbridge mill. The town of Southampton, near its south end, is the 68th in the order of British population, having 7,913 inhabitants. This canal begins in the tide-way in *Southampton-water* at Redbridge, and terminates at Barlow's mill near the town of Andover; the towns of Rumsey and Stockbridge being on its course. Its rise is equal to $176\frac{1}{2}$ fe., and it is fed at its upper end from Pilhill brook. This line was surveyed by Mr. *James Brindley* in the year 1770, and an act proposed, but the opposition of the land-owners prevented one being obtained, until it had been again surveyed in 1789, by Mr. *Robert Whitworth*; in a few years after which it was completed for use.

Arklow and Ovoca. In 1792, Mr. *William Chapman* surveyed the vales of the Ovoca river in Ireland, and recommended to render the improvement of Arklow harbour, which was then intended, more beneficial to the adjacent country, by connecting therewith a system of small canals up the rapidly ascending vales of the Ovoca, by rising 70 or 80 feet at once in proper places, by some of the substitutes for locks, of which we have before spoken.

Arun River. This navigation has nearly a north direction for 15 or 16 miles in the county of Sussex. To supply coals, and export farm produce, seem its principal objects; which are facilitated by the *Arundel* canal, that joins it near Stopham bridge, and would be further accomplished, were the *Surry iron rail-way* extended to it at Wisborough-green bridge, as was proposed in the year 1801. It proceeds from the sea at Arundel haven to Wisborough-green bridge, passing the town of Arundel in its course.

Arundel Canal. Act 31 of Geo. III.—The general direction is west for about 11 miles, following the course of the river Rother, in the county of Sussex. It is about 12 or 13 miles from, and nearly parallel to, the sea-coast, above which it is but little elevated. The supplying of the inhabitants with coals, and exporting of husbandry produce, seem the principal objects of this canal. It commences in the *Arun* river near Stopham bridge, and terminates at the lower plat near Midhurst, with a side cut of about one mile in length to Haslingbourn bridge in Petworth parish. The line being through the parishes of Stopham, Coldwaltham, Bury, Fittleworth, Ergdean, Coates, Sutton, Petworth, Dunston, Burton, Tillington, Lodsworth, Selham, Ambersham, Easebourn, Woolavington, and Midhurst. This canal is the property of that public spirited nobleman the *earl of Egremont*, but open to the use of the public, on paying certain specified tolls.

Ashby de la Zouch Canal. Act 34, Geo. III.—The general direction of this canal, though in a serpentine course, is nearly north, 40 miles in the counties of Warwick, Leicester, and Derby. It commences near and almost upon the grand-ridge on its eastern side, and near its other extremity is tunnelled through a yet higher side-branch of the great ridge. The conveying away of the coals and lime-stone from this last ridge, and the supply of the towns on its borders by means of the *Coventry* canal, with which it connects, are its principal objects. Coventry, which is near it, is the 24th town for population in Britain, having 16,034 inhabitants; while Hinckley, which is upon the line, has 5,070 persons, and is the 120th in order. Market Bosworth and Ashby-de-la-Zouch are other considerable towns near or on the line; the commencement of which is at Marston bridge near Nuneaton, on the *Coventry* canal, and the termination is by a *rail-way* (of $3\frac{1}{4}$ miles) at Ticknal lime-works; there also is a *rail-way* branch of $6\frac{1}{4}$ miles to Cloudshill lime-work; another to Mr. *Wilke*'s Measham collieries of 5 miles: a cut of $2\frac{1}{8}$ miles to Swadlingcote coal-works; another of $\frac{1}{4}$ mile to Staunton lime-works; another is to be made to Stanton-Harrold park (if desired by the *earl of Ferrers*, the proprietor thereof); and there is another short cut of 200 yards to Hinckley wharf. The first $30\frac{1}{4}$ miles of this canal are level, extending to Oakthorpe engine on Ashby woulds, and forming with parts of the *Coventry* and *Oxford* canals, a level of 73 miles in length, being, without the branches, the longest in the United Kingdoms, and rendered more singular by being on so high a level, as to cross the grand ridge with-

out a tunnel. From Oakthorpe engine to the Boothorpe feeder, 1¼ mile, is a rise of 140 feet, thence the summit level of 4¾ miles extends, through the principal tunnel to its north end; thence to the Cloudshill branch, ¾ of a mile, is a fall of 84 feet, and thence to Ticknal works is it level. The Cloudshill, Swadlingcote, and Hinckley branches, are level with the line, and the Staunton branch falls 28 feet therefrom. On this canal are two tunnels, one near Ashby-de-la-Zouch town of 700 yards in length, and the other near Snareton of 200 yards. At Shackerton and at Snareton there are aqueducts; and at Boothorpe a reservoir with a steam-engine for pumping up its water into a feeder for the summit-level of the canal. The rail-way branches, and some part of the canal were completed previously to May 1802, but it was not until about May 1805, that the whole of the line was completed and opened. The company were authorised to raise 200,000l., the amount of shares 100l. each. Public wharfs are provided on Ashby woulds, and at Green-hills near Sutton Cheney. Sir *George Beaumont*, the owner of collieries at Coal-Orton, to which rail-ways had previously been made at great expence connecting with the *Leicester* navigation, is to be compensated, and the company may purchase certain annual quantities of his coals for such purpose. This company is also bound to indemnify the *Leicester* navigation, and to allow them a rate of 2s. 6d. per ton on all coals carried upon this canal or its branches beyond a certain point from the coal-pits in the neighbourhood of their water-levels or rail-ways. To the *Coventry* canal company they are also bound to pay 5d. per ton for all coals, and some few other articles, which pass upon any part of this canal or its branches, and afterwards upon any parts of the *Coventry*, the *Oxford*, or *Grand Junction* canals, or from either of those canals to this: and for duly enforcing this last compensation, the *Coventry* company are authorised to erect toll-house and bars, and station their own collectors when and where they may chuse upon the works belonging to this company. The rates of tonnage allowed, vary from 2d. to ½d. per ton per mile on different goods, while some articles are to be allowed to pass toll free. Our limits will not allow of stating these particulars, which will be found in *Phillips's History of Inland Navigation*, 4to. *Appendix*, p. 128. In June 1796, a survey was made by Mr. *Whitworth* for connecting the north end of this canal, by means of the proposed *Commercial* canal, with the *Trent and Mersey* and the *Chester* canals, and opening the long wished for communication between London, Hull, Chester, Liverpool, Manchester, &c. for river-boats of 40 tons burthen. In consequence of the failure of this scheme, in the January following, it was proposed to extend this canal to the *Trent* at Burton, and to the *Trent and Mersey* at Shobnall.

Avon River, (*Bath.*) The general direction of this navigation is about S. E., in length 26 or 27 miles, by a crooked course in the county of Somerset, and skirting that of Gloucester: it opens into the *Severn* river, and is most of it a tide-way. The objects of this navigation are as various, as the imports and exports of such large places as Bath and Bristol, and a populous neighbourhood require; besides its connection with the *Kennet and Avon* canal, and the other canals therewith connected. The city of Bristol is the 7th place in the order of British population, having 68,645 inhabitants, and Bath is the 12th, with 32,200 inhabitants. The commencement of this river is in the King's road in the *Severn* river (here about seven miles wide), and its navigation ends at Bath, near the commencement of the *Kennet and Avon* canal. About the year 1803, or 1804, an act was obtained by the *Bristol Dock* company, for converting about 70 acres of the old and crooked course of the *Avon* into a vast floating-dock for ships, and to cut a new channel for the river. About May 1804, these works commenced, under Mr. *W. Jessop*, and great progress has been made towards their completion. Two cast-iron bridges are erecting over the *Avon* near these works; one of them from Clifton-down to Leigh-down will, it is said, be 200 feet high above the surface of the water, and the other sufficiently high for ships to pass under it. That essential appendage, a towing-path, was wanting on this river, until the above company was established, who are making one on each side of the river, from Pill up to Bristol, and one thence to Hanham mills; from which place up to Bath, a towing-path is proposed to be extended, under an act, for which notices have just been given; this last part of the river is also intended to be improved in other respects. We have, also, lately seen a notice for a further application to parliament by the *Bristol Dock* company, for erecting a dam and overfall, with sluices, &c. at Red-cliff in Bedminster, to keep up the water for the new floating docks, and for other amendments of their former acts; in 1796 it was proposed that the *Kennet and Avon* canal should be extended to this river at Bristol. At Bitton below Bath, it was lately proposed, that the *Gloucestershire* rail-way should connect. In 1762, Mr. *Stratford* gave a design for a new stone bridge in Bristol of one arch, 150 feet span, and 32½ feet high, which Mr. *John Smeaton* examined and approved; and in 1765, the last mentioned engineer gave a design and estimate for a floating dock nearly as above; after which, Mr. *Campion* made other designs.

Avon River, (*Salisbury.*) The direction of this navigable river is very nearly north, and its length near 30 miles, in the counties of Hants and Wilts. The general objects of this navigation are the supply of Salisbury, and the adjacent country, and the export of its agriculture products. Near Salisbury, it connects with the *Southampton and Salisbury* canal. Salisbury contains 7,668 inhabitants, and is the 70th place in the order of our population; Fording-bridge, Ringwood, and Christ-Church, are likewise considerable towns on the line. The commencement is at the sea in Christ-Church harbour, and termination at Salisbury. The locks and works of this navigation had not been long completed, before a sudden flood happened, which swept away the greater part of them; in which state it lay until 1771, when Mr. *James Brindley* surveyed its course, and recommended a new canal by the side of the river; this was not however adopted, but the river-works have since been repaired; and the imperfection of them, was, we believe, among the most powerful motives for the adoption, in 1795, of the *Southampton and Salisbury* canal above mentioned. Mr. *Smeaton* examined Christchurch harbour in 1764, and recommended another pier to be built west of the old one.

Avon River, (*Stratford.*) The general direction of this navigation is about N. E. by a crooked course of near 40 miles in Worcestershire and Warwickshire: the lower end thereof is but a few feet higher than the tide-way. The trade thereon is very various, depending in a great measure on the connection which it forms between the *Severn* river and the *Stratford* canal. Tewksbury, Pershore, Evesham, and Stratford, are considerable towns upon it. It commences in the river *Severn* at Tewksbury, and terminates at Stratford on Avon, near the junction of the *Stratford* canal. *George Perrot*, esq. is the proprietor of this navigation, and entitled to certain tolls, which were not to be lessened by the new communication with the *Severn*, which the *Worcester and Birmingham* and *Stratford* canals were to open, but

they were, by the act for the latter concern (33 Geo. III.), to make good any falling off in these tolls. About 1792, the *Stratford and Croperdy* was proposed to proceed from this river at Stratford to the *Oxford* canal.

AXE RIVER. The general direction of this navigation is almost S E. for about 11 miles in length by a crooked course in the county of Somerset: it is but little elevated. Its chief objects are the import of coals, and export of farm produce, Axbridge being the only town of any importance upon it. It commences in the Bristol channel near Uphill, and terminates near Axbridge. An act of the 42d Geo. III. passed, for altering and improving that part of it which is between Bleydon and Axbridge. At Blean the *Bristol and Taunton* canal was once proposed to join this navigation; as the *Exeter and Uphill* also was designed to do at Uphill.

Axemouth and Langport. In 1769, Mr. *James Brindley* surveyed this line, which is nearly north, and about 30 miles in length, in Devonshire, Dorsetshire, and Somersetshire, crossing the south-western branch of the grand ridge. The objects of it seem to have been the supply of coals, exporting the products of the country, and opening a communication between the south coast and the Bristol channel, by means of the *Parret* river. Axminster, Chard, and Ilminster are the principal towns which this line was to approach; commencing in the tide-way at Axemouth, and terminating in the *Parret* river at Langport.

AYRE AND CALDER NAVIGATION. Act 9 or 10 of Will. III. The general direction of the *Ayre* river is nearly west, for about 40 miles by a serpentine course, from which the lowest part of the *Calder* river branches, nearly south-west, by a crooked course of about 15 miles, all in the West Riding of Yorkshire. The first of these rivers, though an internal one, begins near the level of the tide-way, and no parts of either of the navigations thereon are much elevated. The objects of this navigation were at first very considerable, in the imports and exports of the populous, manufacturing, and coal country through which it passes, and they are greatly increased, since it has formed part of the grand communications between the port of Hull, or the German Ocean, and the towns of Manchester and Liverpool, or the Irish Sea, by means of the *Leeds and Liverpool*, *Rochdale*, and *Huddersfield* canals, and others joining them. It connects near Snaith with a branch of the *Don* or Dun river; at Leeds, with some considerable *rail-ways* extending to collieries from the coal-staith; near Wakefield it connects with the *Barnsley* canal. Leeds is the 8th place in point of population in Britain, having 53,162 persons, and Wakefield the 64th, with 8131 persons; Hunslet, near it, is the 104th, with 5799 persons; Snaith, Selby, and Pontrefact, are also considerable places near this navigation, which begins in the *Ouse* river near Armyn (to which place 50 and 60 ton sloops come up), and terminates its north-western branch at Leeds in the *Leeds and Liverpool* canal, and its south-western branch at Wakefield in the *Calder and Hebble* navigation. It has also a branch of canal about $4\frac{1}{2}$ miles to the *Ouse* river at Selby, for shortening the distance to York, &c.; and another of $1\frac{1}{2}$ mile near Mathley, between the *Ayre* and *Calder* rivers, for shortening the voyage between Leeds and Wakefield. The boats generally used hereon are 56 feet long, $13\frac{1}{2}$ wide, and draw 3 feet water, with 28 tons of lading: these boats often go down the *Humber*, and round the coast, to the *Welland* and Great *Ouse* rivers. The proprietors are authorised to exact so high a rate of tonnage as 16*s.* per ton in winter, and 10*s.* in summer, between Leeds and the *Ouse*. It is provided in the *Huddersfield* act, 34 Geo. III., that if any communication is hereafter made with that canal to the eastward, the proprietors of this are to be compensated. The opposition of these parties proved fatal, in 1769, to a canal which Mr. *Brindley* surveyed between *Selby and Leeds*.

BARNSLEY CANAL. Act 33 of Geo. III. The first part of the course of this canal is south, and the remainder west, about 15 miles in length, in the West Riding of Yorkshire: its western end is considerably elevated above the level of the sea. The principal objects of it seem to be the export of coals and paving-stones, and forming a short communication with Rotherham and Sheffield (by the *Dearne and Dove* canal, with which it connects at Eyming wood near Barnsley), and Leeds, Wakefield, Halifax, Manchester, Liverpool, &c. Wakefield is the 64th town in the order of population, with 8131 persons; Barnsley is also a considerable town. This canal commences in the lower part of the Calder river, or *Ayre and Calder* navigation, a little below Wakefield town, makes a turn when it arrives at the Dearne river, and terminates at Barnby-bridge near Cawthorn; there is a branch of $2\frac{1}{2}$ miles to Haigh-bridge in Wooley parish, and rail-way branches to Barnsley town 1 mile, and to Silkstone $1\frac{1}{4}$ mile. From the *Calder* to the junction of the *Dearne and Dove* canal, about 9 miles, is a rise of $120\frac{1}{2}$ feet: this is effected by three locks together, near Agbridge, having a low level or side-cut brought up to near the upper pound, with a steam-engine for pumping up the water again, which is let down by the lockage; by 13 other locks near Watton, and a long side-cut, from which engines pump up the water to supply the pound above these; and, near Bargh-bridge, by 4 other locks, a side-cut, and engine. On the Haigh-bridge branch there are also 7 locks together, with a low side-cut, and a steam-engine for pumping up the water required for lockage. At Eym is an aqueduct-bridge. This canal is adapted to the use of the same sized boats as navigate the *Calder*. It is provided, that any rail-ways or stone-roads, that may be made northward from Barghbridge (or mill) shall be discontinued or removed, if a cut shall be made from the *Calder and Hebble* navigation, to connect herewith; also, that the steam-engine near Warmfield shall be so constructed as to burn its own smoke, to prevent any nuisance to the inhabitants. The company were authorised to raise 97,000l., shares, 100l. each. This canal was completed and opened 8th of June 1799. The rates of tonnage on different articles are various: some fixed at 6d. to 4d. for the whole length of the canal; and various others at 3d. to ½d. per ton per mile, with several exemptions, rates of wharfage, &c. See *Phillip's History*, 4to. *App.* p. 40 to 43. The engineers were Mr. *William Jessop*, Mr. *William Wright*, and Mr. *Goll.*

BARROW RIVER (*Ireland*). This is one of the rivers, for the improvement of whose navigation the Irish parliament granted several sums of the public money, between the years 1753 and 1771, amounting to 13,600l. It is probable that less than the half of this amount, raised and expended by individual proprietors, with that circumspection which self-interest can alone inspire, would have effected what, we are told, this expenditure has left very imperfect. At Portarlington and at Monesteraven this river was to be joined by different branches of the *Grand Canal.*

BASINGSTOKE CANAL. This line of canal was first proposed in 1772, as an extension of, or appendage to, the canal intended for shortening the course of the navigation of the river *Thames*, between *Reading and Maidenhead*; but it was some years before the first act for this was obtained, in 1778; the other act is the 33 of Geo. III. The general direction of this canal is nearly west, by rather a crooked course of 37 miles in length, in the counties of Surry and Hants; the summit-pound thereof of 22 miles in length is upon a high level, near the south-east branch of the grand-ridge on its north side. The principal objects thereof seem the import

of coals, and export of timber and agricultural produce, from and to the *Thames*. Basingstoke and Odiham are considerable towns on or near its line, which commences in the *Wey* river at Westley, (about two miles from its junction with the *Thames*,) and terminates at Basingstoke. A cut of 6 miles in length, and level with the summit-pound, was proposed northward to Turgis Green, but has not yet been begun, as we understand. The first 15 miles from the *Wey* river has a rise of 195 feet by 29 locks to Dadbrook, (the part at each lock being about 7 feet) from whence to Basingstoke it is level: 45 ton boats are used on this canal. At Grewel is a tunnel, part of which intersects the chalk strata, (about ¾ mile in length) that had the misfortune of falling in; but the same has, we are told, been substantially repaired. At Aldershot there is a large reservoir for the supply of this canal, (which was begun in 1788 and completed in 1796, at the expence to the proprietors of 160,000l.) and a feeder from the river Lodden. There are 72 bridges over the canal, and several culverts across, to convey the water from the upper to the lower lands. The company were authorised to raise 186,000l. The prices of freight from Basingstoke to Hamborough wharf, London, for coarse and heavy goods, was, in 1800, 15s. per ton; to the dockyards, as far as Deptford, 16s.; and to Blackwall docks, 17s. per ton for timber, &c. The length of a passage is three or four days. In the year 1796 there was an intention of extending a branch from near Grewell tunnel, of about 22 miles in length, to the navigation that connects with *Southampton water*; about 1794 there was an expectation of its being joined by the canal which will next be mentioned; and in 1801, notices were given of an intended cut from Chilton-moor to Bagshot-green in Windlesham; for want of these or some other junctions that shall throw a greater trade into it, this canal has, though improving, been as yet rather unproductive to the share-holders. In 1800 there was a proposal for extending the *Grand Surry* to meet this canal at the Wey river.

Basingstoke and Hampstead. About the year 1794, a line of canal was projected, and notices given, extending from the *Basingstoke* canal at that town, to the *Kennet and Avon* canal at Hampstead, 2 miles above Newbury, the length of the line was said to be 22 miles; we have since heard nothing of this scheme.

Belfast to Loch Neagh. This line of canal was begun under an act of the Irish parliament several years ago, for forming a communication with the sea at Carrick-fergus Bay and the above inland lake or loch, as also for exporting marble from the quarries thereof near its line.

Belper Canal. In September 1801, notices were given for a proposed canal, rail-ways, &c. from the *Cromford* canal at Bull-bridge, to Black-brook-bridge, through the parishes of Crick, Heage, Ashley, Hay, Belper, and Duffield; all in Derbyshire.

Biggleswade and Hertford. Several years ago a proposal was made, for joining the *Ivel* river at Biggleswade with the *Lea* river at Hertford, by means of a canal passing the town of Hitchin, by which an internal communication between Lynn and London would be opened; but the difficulty of supplying a summit-level near Stevenage with water, seems a greater obstacle than the expected trade would pay for surmounting.

Birmingham (*old*) Canal. Acts the 8th, 9th, 11th, 23d, 24th, and 34th of Geo. III. the last but one of which acts, unites the concerns of this company with those of the *Birmingham and Fazeley* canal below; but as these canals were constructed and remain under distinct provisions in the acts, and take different directions from the town of Birmingham, where they meet, we have deviated from our usual rule and continued them separate in our account. The general direction of this canal is about S. E. and 22⅝ miles in length by a crooked course, through the counties of Stafford, a detached part of Salop and Warwick: it skirts along near the grand-ridge on its eastern side, at so high a level as to cross it near its northern end without any deep cutting or tunnel; and, in that high situation is wholly supplied by reservoirs for flood waters, or steam engines which pump up the water again, after it has been let down for lockage, or out of old and disused coal-pits. The principal objects of this canal are the carrying away of the coals from the numerous mines on its banks and branches, and the manufactured goods of Birmingham to Liverpool, Manchester, &c. It connects near Farmer's-bridge at Birmingham, with the *Worcester and Birmingham*, at Tipton Green with the *Dudley* canal, and near Wolverhampton with the *Wyrley and Essington* canal. The great towns on and near the same are, Birmingham, the 6th in the order of population, containing 73,670 inhabitants: Wolverhampton, the 33d, with 12,565 persons; Walsal, the 47th, with 10,399 persons; Dudley, the 49th, with 10,107 persons; and Bilston, the 87th, with 6,914 persons: in the centre of so large and active a population as this, the wonder in a great measure ceases, that this canal, constructed and carried on under such peculiar disadvantages, should nevertheless have proved the most lucrative concern of the kind in the kingdom. This canal commences in the *Staffordshire and Worcestershire* canal at Aldersley or Autherly, near Wolverhampton, and terminates in the *Birmingham and Fazeley* canal, at Farmer's-bridge, near the upper end of the town of Birmingham, the line being double in two places, viz. at Tipton, where a tunnel of near 1000 yards, and a canal of 1⅛ mile in length, between Bloomfield and Deepfield has been made since 1794, for avoiding a zig-zag loop round Tipton hill, of 4 miles; also at the Smithwick locks, where two canals with 3 locks on each have been made, since 1787, for accommodating the immense traffic which is hourly passing. The collateral cuts are very numerous, the principal one extends from near Bromwich to the town of Walsal, by a crooked course of 8¼ miles; from this branch nine or more branches strike off to as many coal-works, &c. on each side of it; the termination of some of these are, near Wednesbury town, at Broad-water engine, Toll-end, Bradley, Bilston, David's Ram-farm, and other coal-works: the lengths of all which are several miles. From the line there is also a cut of about one mile, to Oker-hill coal works; another to Messrs. *Bolton and Watt's* famous Soho foundery, and another to Newhall-ring bason and wharf in Birmingham. In the first mile and three quarters, the rise from the *Stafford and Worcester* canal is 151 feet, by means of 20 locks, then 18¼ miles are level; a descent of 18 feet then takes place, by 3 locks (on each of the two branches before-mentioned); the remainder of the line about 4⅜ miles is level, to the junctions of the *Birmingham and Fazeley* and the *Worcester and Birmingham* canals at Farmer's bridge. The Walsal branch, where it leaves the line, has a fall of 18 feet by means of 3 locks, and about two miles further near Rider's-green, a further fall of 48 feet by 6 locks, whence to Walsal is level; the Toll-end branch has a rise of 15 feet by 3 locks, and the Bradley of 20 feet by 4 locks, all the other cuts being level. This canal was originally cut 28 feet wide at top, 16 at bottom, and 4½ deep; but by constant wear and widening it is now 40 feet wide at the top on the average. The locks are 70 feet long and 7 wide in the clear, and the boats carry about 22 tons. At the coal-wharf near Farmer's-bridge, and at its side cuts, 40 boats can unload at the same time; the Newhall-bason of 2 acres, is for the unloading and loading of timber, stone, slates, and general merchandize, no wharfage is charged at either of these wharfs. Originally, there

was a summit-level on the line of about one mile in length at Smithwick, 18 feet higher than at present, (of which 1000 yards was deep-cutting, 28 feet in the deepest part) and it was supplied until 1787, by a steam-engine at each end; when, owing to the increasing trade, this summit was cut down, and 6 locks removed, making the deep-cutting one mile in length, and 46 feet deep in one place; and though this work was 2½ years in hand, and cost 30,000l. yet it was so managed, that the passage of boats was only 14 days interrupted thereby. There is a considerable reservoir near Oldbury, and another near Smithwick, with feeders for conveying their waters into the summit level. The celebrated Mr. *James Brindley* was the original engineer, and on the 6th of November 1769, he completed 10 miles of the line and branches next Birmingham, by which coals were first brought by water to that great town from near Wednesbury, and their price to the inhabitants was lowered at once from 15s. and 18s. to 7s. 6d. per ton! In October 1772, the line was opened, and in June 1799, the Walsal branch was completed. The proprietors were authorised to raise 115,000l. before the consolidation of this and the *Birmingham and Fazely* concerns. At first the shares of this were 100l. each; but were by the second act 9th Geo. III. reduced in number and made 110l. shares; those created since the 24th Geo. III. are 170l. shares. The original tonnage on all goods, (excepting lime stone) was 1½d. per ton per mile, and for lime-stone and lime, ½d. per ton, except for manuring of the lands of the adjoining proprietors, and road materials were allowed to pass toll-free; but the subsequent alterations in the several acts since would much exceed our limits to mention, those who are desirous of further information will find it in Mr. *John Cary's Inland Navigation*, 4to. pages 36 to 45. By the *Dudley* act, 25th Geo. III. this company are entitled to certain tolls on goods passing on or off of that canal to this; and, by the *Wyrley and Essington* act (32 Geo. III.) to other rates for the junction therewith; all which may be seen as above. About the year 1790, a cut was proposed from this canal (instead of the Dudley junction) to Netherton collieries 12¼ miles, by a tunnel through the grand-ridge near Oldberry, of 2,078 yards, and 184 feet under the hill: in 1796, a foundery and large works belonging to Messrs. *Bolton and Watt*, were erected on the banks of this canal 5 miles from Soho. This canal extending across a country full of coal, it was apprehended that the sinking of the old pits might damage the same, and the company have power to enter and examine mines to prevent their working within 12 yards of the canal, except by passages of 4 feet wide, and 6 feet high: for want of more strict attention to this, some of the branches near Wednesbury have been undermined and broke in, so as to cause the canal to be abandoned in that part. From some of the old worn out coal-mine shafts near Billstone, a lambent blue flame arises in the night, of which a great deal has been said and written. Proprietors of mines within 1000 yards of this canal, or its branches, may make *rail ways* thereto.

Birmingham and Fazeley Canal. Acts 23d, 24th, 25th and 34th of Geo. III.; the second of these acts is for consolidating this concern with the old *Birmingham* above; but each part of the canal remains subject to its own original regulations, as above observed, and the last but one is for consolidating 5½ miles of the *Coventry* canal herewith, subject to the original powers of the *Coventry* act (8th Geo. III.) under which it was set out and made. The general direction of this canal is S. W. exclusive of the late Coventry part, which lies in a direction between N. and N.W. from the original termination at Fazeley: the length of the whole is 20¼ miles in the counties of Stafford and Warwick: the whole of this line of canal is considerably elevated, but particularly the S.W. end in the town of Birmingham, which is situate near the grand-ridge on its eastern side. The great objects of this canal are, the export of the manufactures of Birmingham towards London or Hull, and of coals; the supply of grain and other articles to Birmingham and its populous and busy neighbourhood; it connects with the *Wyrley and Essington* canal near its commencement at Whittington-brook, with the *Coventry* at Fazeley, with the *Warwick and Birmingham* at Digbeth, and with the *Worcester and Birmingham* canal near its termination at Farmer's-bridge. Birmingham, as before observed, is the 6th British town, with 73,670 inhabitants, and Tamworth near the line, is a considerable place. The commencement of this canal is in the detached part of the *Coventry* canal, at Whittington-brook, and its termination in the old *Birmingham* canal at Farmer's-bridge at the top of Birmingham town. From the N.E. entrance of the town of Birmingham, a branch skirts the town to the lower part of it called Digbeth, and there connects with the *Warwick and Birmingham* canal. From the detached part of *Coventry* canal at Whittington-brook, to its junction with the line of that canal at Fazeley, and thence past the small aqueduct bridges near Middleton-hall, about 8¼ miles are level with the *Coventry* canal; from thence to the aqueduct bridge over the Tame river at Salford, 9¾ miles, has a rise of 90 feet by 14 locks, thence to the Digbeth branch, near 1¼ mile, has a rise of about 71 feet by 11 locks; thence to the old *Birmingham* canal at Farmer's-bridge, about 1½ mile, is a rise of about 85 feet by 13 locks; the Digbeth cut, of about 1¼ mile in length, has a fall of 40 feet, by 6 locks to the *Warwick and Birmingham* canal. The width of this canal is about 30 feet, and its depth 4½ feet. The locks are 70 feet long and 7 wide in the clear, carrying boats with about 22 tons of lading. There are a wharf and bason at Digbeth for the accommodation of the lower part of Birmingham. The Salford aqueduct bridge has 7 arches over the Tame river of 18 feet span each. The Digbeth cut is tunnelled or rather arched over in the town of Birmingham; there is also a short tunnel on the line where the Liverpool road crosses. The *Coventry* company being unable for want of money to proceed with the essential part of their line, between Fazeley and Fradley, where it joins the *Trent and Mersey* canal, the latter company for the sum of 500l. over and above the actual expences, undertook to complete this length, by agreements of the 29th October 1783, which the act (of 23d of Geo. III. above) confirmed; this they accomplished, the half nearest to Fradley in January 1787, which the *Coventry* company in Oct. 1787 purchased of them, agreeable to the 23d Geo. III. (which occasions them now to have a detached length of canal); the other half, between Whittington-brook and Fazeley, was completed in October 1789, and on payment of the cost thereof by this company, it was conveyed and made over to them, agreeable to the act above quoted. On the 12th of July, 1790, the aqueduct bridge at Salford being completed, as well as the line of canal, the same was opened, and the water communication between Birmingham and Hull or London, was thereby effected. The sums of money to be raised for this canal, were not distinguished in the acts from what was intended for the extension and improvement of the old *Birmingham* canal, the amount of each share was 170l.; but the act 24th Geo. III. limiting the number of shares to 500, they seem now to be variable. The rates of tonnage are too complicate for us to attempt their particulars, and we must refer the readers to *J. Cary's Inland Navigation*, pages 40 to 44, and pages 75 and 77. By the *Warwick and Birmingham* act (33d Geo. III.) certain duties are secured to this on goods passing from or to that canal, which may be seen in *Cary*, page 44. It is provided

that the tonnage per mile on coals, is to be the same on this and the *Coventry* and *Oxford* canals.

Bishopstortford and Cambridge. In the year 1785 Mr. *John Phillips*, in a quarto treatise, recommended a line of canal from the *Stort* river, at Bishopstortford, to the *Cam*, at Cambridge, either by way of Littlebury and the Granta river, or near to Royston by the upper part of the Cam; which might be done, he says, for little more than 20,000l. but no levels, or other essential particulars are given; nor do we hear of any such, when Mr. *R. Dodd* again revived this idea in 1803, and wished to make this line part of his *North London* canal.

Bishopstortford to Wilton. In 1789 Mr. *John Rennie* was employed by several gentlemen of Essex to survey and report on a line of canal from Hiss, near Wilton, on the Brandon or Little *Ouse* river, at the edge of the fens in Suffolk, to the *Stort* river at Bishopstortford; the distance from the little *Ouse* to Ugley, the beginning of a proposed tunnel (of ¾ of a mile) near Essingham, 45¼ miles, with a rise of 251⅓ feet; thence to Fuller's-end, near Essingham, 2¾ miles, and level; and thence to the *Stort* at Bishopstortford, 4½ miles with 80 feet fall; a cut was proposed to Burwell on a branch of the *Cam* river, and it was to cross the *Lark* river. Several large reservoirs were designed, and three tunnels, two of them being necessary to reach the town of Saffron-Walden, and to miss Audley park. The estimate was 175,000l. and a bill was brought into parliament, in 1790, for the same, but it there met a fatal opposition.

Blackwater Navigation (*Ireland*). This river falls into Loch Neagh, and for extending a navigation therefrom to the Dungannon and Tyrone collieries, the Irish parliament, between 1753 and 1770, granted various sums of the public money, amounting to 11,000l.; a canal with 8 locks, terminating in a bason, was constructed before Mr. *Davis Dukart* the engineer was employed thereon; who, finding the three miles with 200 feet rise, which remained to do to reach the Tyrone collieries, to be too great for a canal with locks, he constructed, about 1776, four water-levels, with three inclined-planes, of 70, 60, and 50 feet rise, to connect them, on which small boats were made to ascend and descend, as we have already mentioned, these being the first *inclined-planes* for boats brought into use in the United Kingdoms; it appears, however, that these were soon laid aside in this place, and a *rail way* was substituted. This navigation was intended to connect with the *Newry* canal.

Blyth River. This river, between Northumberland and a detached part of the county of Durham, appears to be navigable but a small distance above Blyth harbour; but we understand it has several considerable *rail-ways* connecting with it, for bringing down the produce of the collieries to the shipping.

Boyne River (*Ireland*). This is one of the rivers on the east coast of Ireland, for which the parliament, between 1768 and 1771, granted 9,507l. for improving its navigation. At Edenderry it was proposed to be joined by a cut from the *Grand Canal*.

Bradford Canal. Acts 11 and 42 Geo. III. The general direction of this short navigation is south nearly, and 3 miles in length, in the West Riding of Yorkshire. It is not considerably elevated: its objects are the export of coals, iron, and stone, the produce of the neighbourhood of Bradford, and the supply of Bradford town, which is the 95th in the series, with 6,393 inhabitants. It commences in the *Leeds and Liverpool* canal at Winhill, in Idle parish, and terminates at Bradford, where *rail ways* of considerable extent connect with it, one of them goes to the collieries and iron-works on Wibsey Slack; and the descent is so steep that the waggons run down without horses, having their velocity regulated by a man who rides behind and uses the convoy or brake upon the wheels, as occasion requires. From the *Leeds and Liverpool* canal to Bradford is a rise of 81 feet by 8 locks; the width of the canal at top is 24 to 30 feet, and its depth is 5 feet; the locks are of the same width and length as those of the *Leeds and Liverpool* canal. The company were empowered to raise 6000l. in 100l. shares. Boats passing the whole or any part of the distance on this canal are to pay 6d. per ton for clay, bricks, stone, coals, lime, dung, and manure; and 9d. for every ton of iron, timber, and all other goods. This canal was finished in 1774. The last act was found necessary, in order to make good the title to some lands which had been long before purchased for the works.

Brecknock and Abergavenny Canal. Acts 3; and 44 of Geo. III. The general direction of this canal is about N.W. 33 miles in length, in the counties of Monmouth and Brecknock in South Wales; it begins a few miles from the coast, and soon after comes near and follows the course of the Uske river, no part of it being very greatly elevated. Its objects are the exportation of coals, iron, and other mineral products of the country round Abergavenny, by means of the *Monmouthshire* canal, and the supply of Pontypool, Abergavenny, Crickhowel, and Brecon towns, that are near its course. It commences in the *Monmouthshire* canal, 1 mile from Pontypool, and terminates at the town of Brecon; it has several *rail-way* branches: viz. to Abergavenny 1 mile; to Wain-Dew collieries and iron-works 4¼ miles (near 2¼ miles of this last being double on each side of the brook); and, to Llangroiney 1¼ mile. From the *Monmouthshire* canal, the first 14½ miles are level, to 3 miles above the Abergavenny branch, thence to Brecon is 18½ miles, with a rise of 68 feet. Near its commencement it crosses the little river Avon, on an aqueduct, and shortly after passes a tunnel of 220 yards in length. The engineer is Mr. *T. Dadford* jun. The Wain-Dew rail-ways, and the canal above them, up to Brecon, appeared to be finished in June 1802, and by this time we expect the whole is completed, or nearly so. The company were at first authorized to raise 150,000l. and a further sum by their second act, shares 100l. each. The rates of tonnage are to be the same as those on the *Monmouthshire* canal, which see in *J. Phillips's History*, 4to. *App.* p. 18. Horses, mules, and asses are to pay 1d. and cows, or neat cattle ½d. each at certain toll-gates on the rail-ways. The *Monmouthshire* canal, on account of the great benefit this will confer on it in tonnage, agreed to pay this company in March 1794, the sum of 3000l. In May last (1805) it was proposed to extend a rail-way branch from this canal to connect with the river *Wye*.

Bredon Rail-way. About the year 1793 it was in contemplation to make a rail-way and canal from the famous lime-works at Bredon to the *Trent* river, opposite to Weston Cliff; and in consequence, a clause is inserted in the *Derby* canal act, of 33 Geo. III. binding them to make a cut from the *Trent* at Weston Cliff to the *Trent and Mersey* canal, which runs parallel with the *Trent*, whenever this scheme shall be adopted, in order to give this lime a readier course into Derbyshire.

Bridgewater's Canal. Acts 32 and 33 of Geo. II., the 2d, 6th, (*Trent and Mersey act*) and 35th of Geo. III. The general direction of the principal line of this canal is nearly N.E. (and not a great way from its eastern end, a main branch goes off in a N.W. direction nearly); the length is 40 miles, in the counties of Chester and Lancaster. It begins in the tide-way; above which the whole of it is elevated 82 feet at low-water, except about 600 yards, which the locks

occupy to gain this ascent. The great objects which induced the late excellent and patriotic *duke of Bridgewater* to undertake and to expend a princely fortune on the completion of this canal were, the supply of the town of Manchester with coals from his estates near Worsley; the cheaper and more expeditious conveyance of goods, between Manchester and Liverpool, than the *Mersey and Irwell* river navigation then furnished; and between both of these places and the interior and most remote parts of the country, by means of the *Trent and Mersey* (which it joins at Preston Brook,) and its connecting canals. Other and more direct communications have since been made between it and the interior and eastern parts of the kingdom, by means of the *Rochdale* canal and those connecting therewith. Manchester is the 2d place in Great Britain for population, having 84,020 inhabitants, Liverpool the 4th with 77,653 inhabitants, and Warrington the 45th with 10,567 inhabitants, these towns being near this canal. The commencement of this canal is in the estuary of the *Mersey* river at Runcorn-gap, and one of its terminations in the *Rochdale* canal at Castle Field in the town of Manchester, the other (or Worsley branch) is at Pennington near the town of Leigh, the junction of these branches being at Longford bridge; near Manchester there is a communication with the *Mersey and Irwell* navigation, and *Manchester Bolton and Bury* canal, by means of Medlock brook. Under the town of Manchester are arched branches of the canal of considerable length, from one of which coals are hoisted up by a coal-gin, through a shaft out of the boats below, into a large coal-yard or store-house in the main street, at which place the duke and his successors, are by the first act bound to supply the inhabitants of Manchester at all times with coals at only 4d. per cwt. of 140lb.; a circumstance which must have had a great effect on the growing population of this immense town within the last 40 years. At Worsley is a short cut to Worsley mills, and another to the entrance bason of the famous under-ground works or tunnels, of 18 miles or more in length in different branches and levels, for the navigation of coal-boats; some of which are as much as 60 yards below the canal, and others 35½ yards above the canal; these last, to which the boats ascend by means of an *inclined-plane*, that we have already described, extend to the veins of coal that are working at a great depth under Walkden Moor. Most of these tunnels are hewn out of the solid rock; from the lower one, the coals in boxes are hoisted up out of the boats, as they are in Manchester town mentioned above, and the whole of the lower works are prevented from filling with water, by large pumps worked by the hydraulic machine, which we have already mentioned in this article, and the water is thereby always kept at the proper height for navigation on the lower canal. Near Worsley, a branch of about 1½ mile in length, proceeds on to Chat-Moss and there ends, across which celebrated morass, it was by the first act intended to proceed, to the *Mersey and Irwell* navigation at Hollin Ferry near Glazebrook; but, like the cut proposed by the side of the Mersey to Stockport (7½ miles with a rise of 60 feet) was never executed, and the necessity for them is now in a great measure done away, by other plans which have been carried into effect. The rise of 82 feet in the first 600 yards from the *Mersey*, by 10 locks, is the only deviation from one level on this canal (except in the Worsley coal-mines above mentioned); and this length of level water is further increased; by 18 miles on the *Trent and Mersey* canal which connects therewith, making in all 70 miles of level. The width of the canal at top is 52 feet on the average, and depth 5 feet; the boats that navigate between Worsley mines and Manchester are only 4½ feet wide, the others are 50 ton boats or upwards; there are also numerous boats for passengers; large warehouses have been built for goods, at the Castle Field in Manchester adjoining the canal.

Besides the tunnels under Manchester and at Worsley mines, we have been through a short one in passing a gentleman's house and a church, we think at Groppenhall. On this canal are three principal aqueduct bridges over the *Irwell* at Barton, where it is navigable, and over the Mersey and Bollin rivers, besides several smaller ones, and many road aqueducts. There are also several large embankments, one over Stretford meadows, is 900 yards long, 17 feet high, and 112 feet wide at the base; that at Barton bridge is 200 yards long, and 40 feet high; at Bollington is also a stupendous embankment. The principal feeders for this canal are Worsley brook, and the mine-water there collected, the Medlock brook at Manchester, and the lockage of the *Trent and Mersey* canal; and water, which never was scarce in this canal, must now abound, since the increase of supply by the lockage of the *Rochdale* canal.

Mr. *James Brindley*, the engineer, owed much of his well earned fame to the happy contrivance and complete execution which he displayed in every part of this great concern; since the decease of Mr. Brindley, Mr. *Gilbert* and Mr. *Benjamin Sothern* his Grace's agents, have done themselves great credit, by the masterly manner in which they have conducted the canal concerns of their noble employer, and improved and extended his works, as Mr. *Thomas Bury* has also in the mining department, so intimately connected therewith. The tunnelling at Worsley, and the canal between that and Manchester, were begun immediately on the passing of the first act; on the 17th of July, 1761, the Barton aqueduct was completed, and coals were soon after conveyed thereby to Manchester. On the 31st of December, 1772, the 10 locks at Runcorn were opened; in August, 1774, two packet-boats began to proceed regularly part of the way between Manchester and Liverpool, and on the 21st of March, 1776, the whole of the works which were then intended were finished; the extension to Leigh has been made since 1795. The illustrious *duke of Bridgewater*, justly stiled *the father of British Inland Navigation*, died greatly lamented in March 1803, and left this immense concern, (which cost at first 220,000l. it was said, and probably in the whole twice that sum, as the tunnelling at Worsley alone has been estimated at 168,960l.), to *earl Gower*, the present proprietor, whose second son is to inherit it; the net profits are said now to be from 50 to 80,000l. annually. The tonnage has not been increased since the first act, although the length of the canal has been increased to nearly four times what was at that time intended; boats may navigate the whole course or any part on paying 2s. 6d. per ton. Vessels passing out of the *Trent and Mersey* at Preston-Brook and into the *Mersey* at Runcorn, or the reverse, pay :d. per ton per mile for that distance; and all vessels passing to or from the *Rochdale* canal to this canal at Manchester are to pay, for paving stones 4d. per ton, and for all other articles 14d. per ton. It is provided, that flour shall not pay any tonnage on this canal, if the wheat whereof it was made had already paid. Irrigation, or watering of meadows, is practised in a very judicious and profitable manner, by water let out of this canal at Worsley and other places. The price of land-carriage for goods between Manchester and Liverpool was, on the passing of the Duke's third act, 40s. per ton, and by the navigation on the *Mersey and Irwell* 12s. per ton, but his Grace limited his price to 6s. per ton: yet, such has been the increasing trade of these two places, that it was in 1794

ferioufly maintained, and made the ground of another propofed navigable communication, by a junction of the *Manchefter Bolton and Bury*, and the *Leeds and Liverpool* canals, that both the Duke's canal and the river navigation were inadequate to carry the trade between Manchefter and Liverpool, and that the moft frequent and ruinous delays were experienced by the merchants. In 1802, we find the idea again revived of a cut from the *Leeds and Liverpool* canal to the Leigh branch of this canal. About 1772, the *Liverpool and Runcorn* was propofed as an extenfion of this canal from Runcorn; in 1799, the *Manchefter Bolton and Bury*, was propofed to be joined directly with this canal, by means of aqueducts over the Irwell and Medlock at Manchefter.

Briftol and Gloucefter. In the year 1797, we were told, that furveys were making of the line for a propofed canal from the Bath *Avon* at Briftol to the *Severn* at Gloucefter, and alfo, of a continuation of the fame acrofs the Stratford *Avon* to the *Severn* at Worcefter.

Briftol and Taunton. Several years ago, a canal was propofed, we are told, from the *Avon* river at Briftol to the town of Taunton, with cuts to Nailfea collieries, to the *Axe* river at Brean, and to the town of Langport, but we are not further acquainted with its objects or particulars.

Brothic River. This is a fmall river on the coaft of Angers county in Scotland, and navigable, we believe, but a fmall diftance up from the harbour of Aberbrothick at its mouth, which harbour is of great antiquity, and appears to have had piers and works erected for its improvement and fecurity, fo long back as the year 1194; the fpring tides here rife 15 feet.

Bude and Hatherleigh canal. In 1793, the *earl of Stanhope* propofed a line of water-levels and rail-ways, between the fea in Bude Haven, on the Briftol-Channel part of the Cornifh coaft, and the neighbourhood of Hatherleigh in Devonfhire, paffing the town of Holdfworthy, for carrying up fea-fand, (which in this bay confifts of a congeries of broken fhells), as a manure, and exporting of farming produce; the rife on this line was upwards of 500 feet, up which his lordfhip propofed, that his 2 ton boats fhould be conveyed at proper intervals on inclined-planes, whofe peculiarities have been already mentioned in this article. In April laft (1805), we find a fcheme on foot, for improving the harbour of Bude and building a pier for the protection of fhips.

Bude and Launcefton, or the Tamar canal. This is one of the few inftances, in which an act (14th of Geo. III.) was obtained, without any part of the fcheme having been carried into effect. Mr. *Edmund Leach* the projector of this, in his Treatife on Inland Navigation, propofed, that it fhould proceed from the tide-way in Bude Haven, Cornwall, on the Briftol Channel, and proceed near to Launcefton, and into the tide way in the river *Tamar* near Calftock, in the S.E. part of Cornwall. There was a provifion, that the powers of the act were to ceafe in 10 years, if the canal was not proceeded with; it was propofed, to purchafe only 39 feet wide of land, and not to be allowed to cut more than 39 inches deep into the earth on the lower fide, in any part, except for docks, &c.; the canal to be 21 feet wide at top and 12 at bottom, with a towing-path on each fide of it, 10 ton boats to be ufed; the direct diftance of the two extreme points is only 28 miles, but owing to the extremely ferpentine courfe of the level which was to be followed, its propofed length was 81 miles, and was eftimated to coft 1000l. per mile. Locks were not to be ufed, but *inclined-planes* for boats of Mr. Leach's contrivance, of which we have already given an account in this article. From the fea at Bude, was to be a plane of 54 feet rife, thence a level of 6½ miles, then a plane of 120 feet rife, then 4 miles of level, and a third plane of 66 feet rife to the fummit-level, which extended 34 miles to Launcefton town, and 34 miles beyond; then, a plane with a defcent of 120 feet, then 2½ miles of level, and a fifth plane, at Kelly Rock, of 120 feet fall to the *Tamar* navigation. A cut or feeder of 3 miles was propofed, from the Tamar is Lanells to St. Tankins on the Pack-faddle (being a low point on the fouth-weftern branch of the grand-ridge). Mr. Leach, however, tells us, that thefe levels are not to be entirely depended on, and mentions 258 feet as the elevation of the Pack faddle. The principal objects of this canal were the carrying of falt and fhelly fand from the coaft into the interior of the country as manure (an object fince in part accomplifhed by the *Tamar manure*, and the *Stover* canals). In 1785, Mr. *Leach* wifhed to revive this project, and to fhorten the courfe to 40¾ miles, by cutting down the fummit 18 feet, and making a tunnel of 100 yards; and to form another communication with the fea at Weedmouth-bay, where the fame broken fhells abound; the coft was now eftimated at 53,100l.

Burrowstowness Canal. The act of the 8th of Geo. III. (for the *Forth and Clyde* canal) eftablifhed a fet of proprietors for this canal; its direction being nearly weft for about feven miles in the counties of Linlithgow and Stirling, in Scotland; from the tide-way in the harbour of Borrowftownefs, on the Firth of *Forth*, to the *Forth and Clyde* canal, near its eaftern termination at Grangemouth. Its objects are ftated to be, the avoiding part of a dangerous and difficult navigation on the *Forth*, and for improving the lands of Kinniel and Beercrofts, through which it paffes. Burrowftownefs, Linlithgow and Falkirk are confiderable towns near this line. The depth to be feven feet, and width and fize of the locks at the entrance proportionable thereto, the canal being level. The company are authorifed to raife 8,000l. the fhares to be 50l. each. The tonnage of lime, lime-ftone, and iron-ftone ½d. per ton per mile, all other goods and articles (except road-materials and manures) 1½d. per ton per mile.

Burry River. This river, or eftuary, connecting with the Briftol Channel, is between the counties of Caermarthen and Glamorgan, in South Wales, and is navigable a diftance of ten or eleven miles to Lwghor or Llougher, in nearly an eaft direction; at the flats in Llanelly it is joined by the *Caermarthenfhire* rail-way, and another rail-way has lately been laid from this river to the Penclawdd copper-works: in 1801, the *Llandorry and Llanelly* canal was propofed to join at the Spitty in Llanelly; and, in October 1805, a wet dock was propofed to be made on the eaft fide of the Llanelly pier, to communicate with the *Caermarthenfhire* rail-way.

Caerdyke. This is an artificial channel or ditch, as ancient as the time of the Romans in this country, from the *Nen* river, a little below Peterborough, to the *Witham* river, three miles below Lincoln, of near 40 miles in length; it appears to have been very deep, though now almoft grown up; and it is rather doubtful whether it ever was intended or ufed for the purpofes of navigation.

Caermarthenshire Rail-way. Act 42 Geo. III.—The general direction of this line of rail-way is nearly north for 14 or 15 miles in Caermarthenfhire; it commences on the coaft, and is not very greatly elevated in any part; its general objects are the export of coals, iron, lead, &c. from the country through which it paffes. Llandillo Vawr is the only confiderable town near its courfe. It commences in the *Burry* river, at the new bafon for fhips, at the flats near Llanelly, and terminates at Caftel y-Garry lime-works in Llanfihangel Aber-bythick. In the deep cuttings for

this rail-way near Munydd Mawr several unknown veins of good stone-coal were discovered, and some of lead ore; in November 1804, the embankment near this place, consisting of more than 40,000 cubic yards of earth was completed, with the rail-way upon it. In October 1805, it was proposed to make a wet-dock for ships at the commencement of this line, on the east side of Llanelly pier; in 1801, the *Llandovery and Llanelly* canal was proposed to pass through nearly this line of country.

Caistor Canal. Act 33 Geo. III.—The direction of this line is east 9 miles in the county of Lincoln; it is but little elevated above the sea. Its objects seem the importation of fuel and other articles, for the supply of Caistor town, and the export of farming produce: it commences in the *Ancholme* navigation, at South Kelsey, and terminates at the town of Caistor. The company were empowered to raise 25,000l., shares 100l. The rates of tonnage are from 2d. to 8d. per ton per mile on different goods, with other rates for corn, &c. See *Phillips*'s 4to. *History*, p. 47. All stores for the use of government, or materials for roads, to pass free at all times, and manures for the adjoining lands, when the waters run over the lock-weirs. In 1801, there was a proposal for extending this canal from Caistor, along the foot of the Woulds, southerly, to Hambleton Hill, in Tealby, near Market-Raisin, the expence of which was estimated at 6,500l.

Calder and Hebble Navigation. Act Geo. III.—The general direction of this navigation is nearly west, about 23 miles in length, in the west riding of Yorkshire; it has a considerable elevation above the sea at its west end: the general objects are the communication between Liverpool, Manchester, and Hull, by means of the *Rochdale* and *Huddersfield* canals, and *Ayre* and *Calder* rivers, the import and export of goods from Halifax, and the export of paving-stone (now so much used in London, called Yorkshire paving) from the famous quarries at Ealand-Edge and Cromwell-Bottom, and lime from Houghton, Brotherton, and Fairburn: at Cooper's Bridge it is joined by Sir John *Ramsden*'s canal (leading to the *Huddersfield* canal), and at Dewsbury by the *Dewsbury and Birstal* rail-way. Halifax is the 58th British town, with a population of 8,886 persons; Wakefield the 64th, with 8,131 inhabitants; and Huddersfield the 81st, with 7,268 persons. This navigation begins in the *Ayre and Calder* navigation on the latter river, at Wakefield, and terminates in the *Rochdale* canal, at Sowerby-Bridge. There is a rail-way branch of about half a mile to Bradley collieries; it has a cut of about half a mile in length by the side of the Hebble river, to Salter-Hebble; and provision is made (in 33 Geo. III. for *Barnsley*) for a cut to Bargh-mill, on a branch of *Barnsley* canal; there are several locks; one of them near Salter-Hebble, of 10 or 12 feet rise, was in 1783 removed, and two new ones, of half that height, with a bason between them, were substituted by Mr. *William Jessop*; some of the locks here erected in 1761, by Mr. *Smeaton*, have single gates at their heads. At Salter-Hebble are a bason and large warehouses, and others at Sowerby Bridge, for the accommodation of the town of Halifax; near Ealand is a large weir across the *Calder* river. This navigation was planned or superintended by Mr. *James Brindley*, and afterwards by Mr. *John Smeaton*. About 1765, the navigation was brought up to Ealand quarries, and about 1776, to Salter-Hebble, and to Sowerby-Bridge warehouses. The stone and white slate from Ealand-Edge are carried in carts and four-wheeled carriages, to be put on board of the keels at Bridgehouse wharf, on account of the great height of the quarries above the *Calder*; the Cromwell bottom-stone is put on board at a wharf there. From the quarries of *Thomas Thornhill*, Esq. at Lillon's Wood, near Ealand, a long and wide inclined plane, of about 45° of elevation, was, about the year 1774, made from the *Calder* river, and paved with large flat stones, on which a sledge descended loaded with stone, and by means of a rope passing over a wheel and axle, drew another empty sledge up the plane; this continued in use for some years; but this quarry was disused before the year 1783. In 1762, a violent flood happened on the *Calder* river, which destroyed many of the works thereon; these Mr. *Smeaton* repaired, and in 1774 another happened, so destructive that the navigation was for near a year suspended, before they were repaired; the fall of this river is no less than 8 feet per mile for more than 20 miles together. By the act 34 Geo. III. for *Huddersfield* canal, this navigation was guaranteed against a diminution of its tolls, by any other communication to the eastward opened therewith. In 1794, the *Manchester Bolton and Bury* canal was proposed to be extended to join this at Sowerby-Bridge. In 1802, the *Wibsey and Dewsbury* rail-way was proposed to join at Raven's Bridge, and notices have in the present autumn (1805) been given for the *Wakefield and Hullet* rail-way, intended to join this navigation at Bottom-Boat, near Wakefield; a side-cut is now making near Bridge-house, for avoiding the mill-dams, and improving this navigation.

Cam River. The general direction of this navigation is about south-west, for 14 or 15 miles in the county of Cambridge; it is but little elevated above the level of the sea; its principal object is the supply of the town of Cambridge, which is the 51st in the order of our population, with 10,087 inhabitants: Ely also, near this navigation, is a considerable place. It commences in the great *Ouse* river, at Harrimere, and terminates in the town of Cambridge. It has a cut or reach of 3 miles to Reche, and another of 3½ miles to Burwell, at which last place the *Bishopstortford and Wilton* canal was, in 1789, proposed to join. The *Cam* river is embanked above the adjoining fens through all its lower parts, is without locks in some parts, and has sluices for making flushes of water, to enable boats to pass the shallows and hards.

Camel River. The general direction of this navigation is about south-east for near 8 miles, in the county of Cornwall; it is within the flow of the tide, and is chiefly used in the import of coals and export of agricultural produce: it connects at Guinea-Port, near Wadebridge, with the *Polbrock* canal. Padstow, on its banks, is a considerable town; it commences in the Irish channel, at Stepper Point, and terminates at Wadebridge.

Canterbury and Nicholas-Bay. In the year 1802, a canal was proposed, and again in 1804, and surveys taken, for a canal on a level, capable of carrying sea-built vessels, between the sea at St. Nicholas Bay, near Margate, to the city of Canterbury, about 10 or 11 miles in a south-west direction, there to connect with the *Stour* river, and with a canal then proposed, called the *Medway and Rother* canal. Canterbury has 9000 inhabitants, and is the 57th place in the order.

Cardiff and Merthyr-Tydvil Rail-way. Act about 35 Geo. III.—This line is nearly in a north-west direction, for 26¾ miles, in the county of Glamorgan, in South Wales. The general object of this rail-way is the export of iron from the great works at Merthyr Tydvil, Dowlais, &c. Cardiff, Caerphilly, and Merthyr are considerable towns on or near this line, which commences at the floating-dock, in the *Severn* at Lower Layer, the termination of the *Glamorganshire* canal, by the side of which, very nearly, it proceeds to Merthyr Tydvil, and thence to the lime-works at Panton, in Merthyr parish; at Quaker's yard a branch of

9¼ miles goes off to Carno mill, in Bedwellty; *Homfray, Hill* and Co. are the proprietors of this rail-way or tram-road, and it was, we believe, constructed under the first act of parliament ever passed for this kind of roads; the width of land allowed to be purchased was 7 yards. On the 21st Feb. 1804, a trial was made of one of Trevethic's high-pressure steam-engines for drawing trams on this tram-road, as before mentioned, and 10 tons of iron and 70 persons were drawn for 9 miles by the power of steam, without the use of condensing-water. At Merthyr there is a curious and stupendous water-wheel, of 50 feet diameter, made of cast-iron.

Caron River. The direction of this river is west, in the county of Stirling, in Scotland, and for 3 miles it is navigable, from the *Forth* river to Caron shore, for vessels drawing 7 or 8 feet water at neap-tides; at Caron shore there is a cut from the *Forth and Clyde* canal; and near Caron shore are the famous Caron iron-works.

Cart River. The direction of this navigation is nearly south, for about 3 miles in Renfrewshire, in Scotland; its objects being the supply, and the exports and imports of the great manufacturing town of Paisley, which is the 15th in the order of British towns, and contains 31,179 persons. Renfrew is also a considerable town near the same: this navigation commences in the *Clyde* river, near Inchinnan, and terminates at the town of Paisley, at which place it was proposed, in 1803, to be joined by the *Glasgow and Saltcoats* canal.

Chelmer and Blackwater Navigation. Acts 6 and 33 Geo. III.—The general direction of this navigation is nearly west for 1⅝ miles in the county of Essex; its general objects are the supply of Chelmsford and its neighbourhood with coals, deals, &c. and the export of farm produce. It commences in the Tide-way, at Collier's-Reach, in the estuary of Blackwater river, and proceeds by the course of the Chelmer river to the bason at Chelmsford town, with a cut near ¼ of a mile to Malden. Chelmsford and Malden are considerable towns. From low-water in the bason at Collier's reach to Heybridge-mill, on Blackwater river, 1⅝ mile, is a rise of 12 feet 8½ inches, thence to Beely or Baily-mill, on Chelmer river, 1¼ mile, is a rise of 7 feet 3½ inches; thence to the bason at Chelmsford is 10¾ miles, with a rise of 59 feet 5 inches: the branch has a rise 6 feet 8½ inches into the bason at Malden. Mr. *John Smeaton* surveyed this line in 1762, and recommended 13 miles of new canal, and estimated the same at near 16,700l.; Mr. *John Rennie* was afterwards employed. The bason at Collier's reach was opened for ships in February 1796; the company were authorized to raise 60,000l. the amount of shares 100l. each; in 1802 these were so depreciated, that they were said not to be worth 5l. each. The spring-tides flow 5 feet at Baily-mill-tail, and 8 feet at Malden bridge; the neap tides do not raise the water above one foot at the last place.

Cheltenham and Tewksbury. In 1801, notices were given for a proposed canal from the *Severn* river, near the junction of the *Avon* therewith, at the town of Tewksbury, to the town of Cheltenham, through the parishes of Tewksbury, Tredington, Elmstone-Hardwick, Uckington, Swindon, and Cheltenham, a course nearly south-east for about 8 miles, in the county of Gloucester. Tewksbury and Cheltenham are considerable places.

Chester Canal. Acts 11 and 17 Geo. III.—The general direction of this canal is about south-east for 18 miles, in the county of Chester; it is not greatly elevated above the level of the sea; its principal objects are the export of farming produce, and the import of coals and lime for Nantwich town, and the surrounding country; it forms a double communication between two points in the line of the *Ellesmere* canal, at Chester and at Franckton common. Chester is the 25th British town, with a population of 15,052 persons. Nantwich is also a considerable town. This canal commences in the tide-way in the *Dee* river, in the town of Chester, near to where the *Ellesmere* canal crosses the same, and terminates at the town of Nantwich; at Stoke, in the parish of Acton, it is joined by the Whitechurch branch of the *Ellesmere* canal; from Chester to Barbridge, near Tiverton, the distance is 14¾ miles, with a rise of 170 feet 10 inches, and thence to Nantwich it is 3¼ miles, and level. The canal passes Christleton, Waverton, Hargrave, Huxley, Brassey green, Beerton-castle, Tiverton, Hurleston, Acton, and Nantwich; there is an aqueduct at Huxley-mill. Mr. *James Brindley*, and other engineers, were employed in 1767, 1769, and 1770; in 1769 an unsuccessful attempt was made to obtain an act for it; it was begun in 1772, and was completed from the *Dee* to Huxley-mill 16th June 1775, and shortly after to Nantwich; a branch was provided for in the act, from Barbridge, 8⅛ miles long, with a fall of 40 feet, to Middlewich, near to the *Trent and Mersey* canal, but not into it. Although this branch, intended for bringing salt to Chester, was not executed, the expences amounted to 80,000l. and the shares became perhaps the most depreciated of any concern in the kingdom, being sold at one time, as we are informed, for one per cent. of their original value. In 1793, a junction was proposed near Nantwich, with a branch of the intended *Sandbach* canal; in 1793, a rival scheme to the *Ellesmere*, called the Eastern Grand Trunk, was proposed to join at Crows-nest; and in June 1796 the *Commercial* canal was proposed to join at the same place, in order to form by means of the *Ashby-de-la-Zouch* canal, and others, a communication for 40 ton boats, between Liverpool, Chester, Hull, London, &c.

Chesterfield Canal. Act 10 Geo. III.—The general direction of this canal is nearly south-west, by a crooked course 46 miles in length, in the counties of Nottingham, York, and Derby; the western end is considerably elevated; its principal objects are the export of coals from near Chesterfield, and lead from the Derbyshire mines, and the import of lime, corn, timber, &c. Chesterfield, Worksop, and Retford are considerable towns upon this line, which commences in the *Trent* river, near its junction with the *Idle* river, at Stockwith, and terminates at Chesterfield town; from the *Trent* to Worksop the distance is 24 miles, with a rise of 250 feet; thence to Norwood it is 9 miles, with a rise of 85 feet; and thence to Chesterfield it is 13 miles, with a fall of 45 feet: the number of locks is 65; the lower part of the canal, from the *Trent* to Retford, is for large boats of 50 or 60 tons burthen; above this the width is 26 to 28 feet, and depth of water from 4 to 5 feet; the boats here used being 70 feet long and 7 wide, and carrying 20 to 22 tons each. In 1794 such boats as these cost, when new, 90 to 100l. each. The boat-owners here usually pay their bargemen by the ton of goods which they convey stated distances, instead of weekly wages. At Norwood is a tunnel through Hartshill of 2850 yards in length, being 12 feet high and 9¼ wide withinside the arch, and 36 feet below the surface of the hill; this tunnel was begun in November 1771, and finished the 9th May 1775; at Drake's-hole is another tunnel of 153 yards in length. Mr. *James Brindley* projected this canal, and directed its execution until his death in September 1772, when his brother-in-law, Mr. *Henshall*, succeeded, and completed the whole in 1776. The tonnage is 1½d. per ton per mile, and in calculating the same ⅛th of a mile is taken into account, and ¼th of a ton. It appears that the canal cost 160,000l. and the shares were at first much depreciated, and sold for a long

time below par; in September last (1805) the profits amounted to 6l. per cent. annually. In Mr. *Brindley's* time, a junction was intended at Chesterfield with the proposed *Chesterfield and Swarkstone* canal; and in 1802, an extension of this canal was proposed of 5 or 6 miles in length, nearly south to Ashover.

Chesterfield and Swarkstone. The late Mr. *Brindley*, about the year 1771, proposed a canal from the *Trent and Mersey* canal at Swarkstone to the *Chesterfield* canal at the latter place, the direct distance being about 25 miles nearly north, the line being through a country very rich in coals. Derby, the 43d town, with 10,832 inhabitants, was to be in the line of this canal, and the town of Belper is also near it.

Chichester Haven. This inlet of the sea, on the coast of Hampshire, is of considerable length, in different branches, navigable for ships, surrounding Thorney Isle, and connecting with Langstone and Portsmouth harbours. Havant and Chichester are considerable towns near it. In September 1805, notices were given for cutting a short canal, to commence with a sea-lock in deep water in this haven, and proceed to Upper Southgate field, in Chichester, there to terminate in a spacious bason or dock.

Clelby River. This river has nearly a north-east course, in the county of Pembroke, in South Wales. It commences in the tide-way in *Milford Haven*, and terminates at Cannister bridge, near Narberth, which is a considerable town; and Pembroke on another branch of the haven is also a considerable place.

Clyde River. Acts 34 Geo. II. and 9 and 11 of Geo. III.—This river or frith commences with a most noble and capacious estuary, in the northern or Irish channel, and extends nearly north, to Gonrook, when its direction changes towards the east, and its width diminishes gradually to Glasgow, where the navigation terminates. Glasgow is the 5th town in Britain, in point of population, containing 77,385 inhabitants: Paisley, in the vicinity of this river, is the 15th town, with 31,179 persons; Greenock, the 20th, with 17,458 persons; and Rothsay, (on the Isle of Bute) the 118th, with 5,281 persons: Ruther-Glen, Renfrew, Dumbarton, Port-Glasgow, Irvine, and Ayr, are also considerable places on or near the banks of this river. At Glasgow bason a branch of the grand *Forth and Clyde* canal joins this, as also the *Monkland* canal, and *Edinburgh and Glasgow* canal; near Inchinnan the *Cart* river joins, and at Dalmure Burnfoot; the western termination of the *Forth and Clyde* canal is in this river; while the navigable lochs and sounds which connect therewith below Dumbarton are both numerous and important; by means of lochs, Fine, and Gilp, there is a connection with the *Crinan* canal. In the year 1805 an act (45 Geo. III.) was obtained by the earl of *Eglinton* and others, for building new piers and improving *Ardrossan* harbour, and building wet-docks, &c. near Saltcoats, on this river, and in this harbour, as well as at Glasgow, the *Glasgow and Saltcoats* canal was, in 1803, proposed to connect therewith; at Rothsay, on the Isle of Bute, piers have been built, and the harbour connecting with this river improved; *Greenock* harbour is also under great improvement, in consequence of an act of 43 Geo. III. The trade on this river is very immense and various; it appears that Greenock alone employed 175,551 tons of shipping thereon in the year 1800.

Codbeck Brook. Act 7, Geo. III.—The direction of this navigation is nearly north for about six miles, in the north riding of Yorkshire, commencing in the *Swale* river near Topcliff, and extending to the town of Thirsk, for whose accommodation it is intended.

Colne River. The general direction of this navigation is nearly N.W. for about 8 miles, in the county of Essex; its objects are the import of coals, deals, &c. and the export of farm produce, and of oysters from the banks below Wivenhoe. Colchester is the 39th place in Britain, with a population of 11,520 persons. It commences with an estuary at Mersey island, and terminates at the town of Colchester, to which place small sea-built vessels can get up. Large ships navigate to Wivenhoe, where there is a dock-yard for building frigates and large trading ships.

St. Columb Canal. The general direction of this canal is nearly east for seven or eight miles, in the county of Cornwall; although near the coast, it is considerably elevated. Its objects are the export of a particular species of stone found about St. Dennis, called China-stone, used in great quantities in Wedgewood's, and other potteries near the line of the *Trent and Mersey* canal, and the import of coals, and of a sea-sand consisting of broken shells for manure. This canal was proposed to proceed across the western branch of the grand ridge to the south coast; not one third of which length has, however, been carried into effect. St. Columb Major, St. Austel, and Grampound, are towns near the line. It commences at the sea-shore of the Irish channel near St. Columb Minor, and terminates at present within about two miles of St. Columb Major; from thence it was to pass St. Dennis, St. Stephen, St. Ewe, and arrive at the sea again near Pentuan, not far from the famous Polgarth mines and engines. The part which was completed about the year 1775, commenced on the top of a very high cliff, and pursued the course above mentioned, without locks, we believe. The canal was a narrow one, and at its west end, the cliff was with great labour hewn down, into a steep inclined plane, that was covered with planks: the canal was conducted to the very top of this plane, and the boats which were rectangular ones, were brought, when loaded with stone, to the termination of the canal, where they were fastened by a sort of hinges; strong ropes were then attached to the stern of the boat, and by means of a wheel and drum, worked by a horse-gin or wem; the boat was hauled up an end, and the stones were thereby shot out, and rolled down the plane to the strand below, from whence boats conveyed them on board the ships. The same wheel and drum was adopted for drawing boxes of coals or Shelly sand up the plane, in order to their being loaded into the returning boats. Near to its eastern termination the canal was conveyed on an aqueduct bridge over a road. We have been favoured with these particulars by a Cornish gentleman, since our account of inclined planes was written, or we should have noticed this (the plane on *Parnel's* canal and another on the *Calder and Hebble*) as early instances of the use of inclined planes for boxes of goods, &c. For seven or eight years this canal continued in use, but whether like the *Mawgan* canal, in its neighbourhood, it has since been disused, we are not at the present moment able to learn.

Commercial Canal. In the year 1796, Mr. *Robert Whitworth* was employed to survey this line, proceeding from the *Chester* canal at Nantwich to the *Ashby de la-Zouch* canal near that town; it was proposed to join Sir *Nigel Grisley's* canal and the *Newcastle under-line* canal, to cross the *Trent and Mersey* canal near Burslem, and proceeding by Uttoxeter, to cross the *Trent and Mersey* canal again, and the *Trent* river at Burton. The objects of this proposed canal were, the forming of a communication for larger boats (40 tons) than the *Trent and Mersey* is calculated for, except below Burton, and contributing towards the wished-for passage of large boats between Liverpool, Manchester, Chester, Hull, London, &c.

Conway River. This river has nearly a south course for

14 or 15 miles, between the counties of Caernarvon and Denbigh in North Wales; its principal object seems to be the supply of Llanrwst and Aberconwy, which are considerable towns. It commences at the tide-way in Conway bay, and terminates at Llanrwst town. In June 1802, it was in contemplation to straighten the course of this river, about a mile below Llanrwst, by a new cut 492 feet long, 88 feet broad at top, and 60 at bottom, with a dam at its upper end across the old crooked channel. At Llanrwst, there is a curious stone bridge of three arches, built by *Inigo Jones*, over this river; and in 1802, it was proposed to construct a stupendous cast iron bridge over it at Aberconway ferry, in order to facilitate the communication with Ireland by way of Holyhead, in the Isle of Anglesea; another iron bridge being intended at Bangor ferry, on *Menai* strait.

Coombe-Hill Canal. Act 32 Geo. III.—The course of this canal is nearly S. E. for $3\frac{1}{2}$ miles, in the county of Gloucester: its general objects are the export of coals from the mines near it, and shortening of the length of land carriage to Cheltenham, which is a considerable town; and so is Tewksbury near its western end. It commences in the *Severn* river at Fletcher's leap in Dearhurst, and terminates at Combe hill in the parish of Leigh, the rise being 15 feet only. This canal was constructed at the sole expence of three persons, viz. *Thomas Burges*, *William Miller*, and *Sarah Mumford*.

Cottingham and Hull. In the year 1802, this line of canal was proposed, about four or five miles in length, in a N.W. direction, in the east riding of Yorkshire, to commence in the *Humber* river at the town of Hull, and extend to the town of Cottingham. The import of coals, deals, &c. and the export of farm produce, and perhaps of chalk, seem to be its principal objects. Hull is the 16th town in Britain, with a population of 29,516 persons.

Coventry Canal. Acts 8, 25, (for *Trent and Mersey*) and 26 of Geo. III.—The general direction of this canal is nearly S.E. for about 22 miles (exclusive of the detached part beyond the *Birmingham and Fazely* canal, and the branch to Coventry) in Staffordshire and Warwickshire. Its situation is high, particularly the eastern part, which crosses the grand ridge near Bedworth, without a tunnel, and its Seeswood branch does the same. Its general objects are the line of communication between London, Birmingham, Manchester, Liverpool, &c. the export of coals from the numerous mines near it, and the supply of Coventry city, which is the 24th on the list of British population, with 16,034 inhabitants. Nuneaton, Atherstone, and Tamworth, are also considerable towns near the line; and Hinckley, the 120th, with 5,070 inhabitants, is also in its vicinity. It commences in the *Birmingham and Fazely* canal at Fazely, and terminates in the *Oxford* canal at Longford; its detached part of $5\frac{1}{2}$ miles in length, commences at the termination of the *Birmingham and Fazely* canal at Whittington brook, and terminates in the *Trent and Mersey* canal at Fradley heath; near to Wittington brook, it connects with the *Wyrley and Essington* canal, and at Marston bridge the line is joined by the *Ashby de-la-Zouch* canal. There is a cut of about one mile in length to Griff collieries, belonging to sir Roger Newdigate; another to several collieries by different branches near Seeswood-pool and Bedworth, five or six miles in length; there is also a cut of half-a-mile from the line to Bedworth; the branch to Coventry is $4\frac{1}{4}$ miles in length, and there is a rail-way branch to Oldbury coal works. The detached part is level with the *Trent and Mersey* canal, which level continues (through $5\frac{1}{2}$ miles of the *Birmingham and Fazely*) to the commencement of the line of this canal at Fazely; from thence to Atherstone, a distance of about 10 miles, the rise is 96 feet, by means of 13 locks; from thence to the *Oxford* canal, about 12 miles, is level; so is the cut to Coventry, and those to Griff, Seeswood-pool, Bedworth, &c. The last or highest level of this canal forms, with part of the *Oxford* and *Ashby* canals, the longest level that is to be found in Britain, being upwards of 82 miles, we believe, including side branches. This is a narrow canal, but the company have bound themselves to widen the same to the width of the *Grand Junction*, if the proprietors of that canal shall at any future time require it. A stop-gate is maintained at the end of the *Oxford* canal at Longford, to prevent this canal, which is sometimes low in Summer, from drawing off their water. Mr. *James Brindley* was the original engineer to this concern, and $16\frac{3}{4}$ miles of the level part from Coventry to Atherstone was completed in 1786, when the works were suspended for near 10 years; at length, the *Trent and Mersey* company undertook to complete 11 miles of this original line north of Fazely; half of which they afterwards sold to the *Birmingham and Fazely* company; and the other half, on the 4th of February, 1787, was purchased by this company, who thus came to have a detached part of their canal. The line of communication was opened by the completion of this canal in June 1790. This company have been authorised to raise 120,000l., their shares being 100l. each. Some years after the completion of this and the *Oxford* canal, the shares herein had obtained the great price of 400l., but owing to the rivalry of the *Warwick and Napton* canal, they were, in 1802, reduced to 350l., and their dividend to 8l. per cent. Since the completion of the *Grand Junction*, this concern has been flourishing, and the dividends are now 16l. per annum per share. The tonnage allowed on this canal is $\frac{1}{2}$d. per ton per mile for lime and lime-stone, and $1\frac{1}{2}$d. per ton per mile for all other articles, (except road or paving materials and manures upon the pounds, or when the water runs to waste at the locks.) On the completion of the adjoining canals, the tonnage on coals was, by their general consent, reduced to 1d per ton per mile upon several of them. It was agreed, between this and the *Oxford* company, (9 Geo. III. *Oxford*) that the latter should be entitled to all tolls, except on coals, that are collected on the first $3\frac{1}{2}$ miles of this canal towards Coventry, for goods passing from the *Oxford* canal, and that this company should in return receive the tolls upon coals collected on the first 2 miles of that canal. The act of 34 Geo. III. for *Ashby-de-la-Zouch* canal, granted to this company 5d. per ton upon all goods (except farming produce, manures, or road materials, or iron or its ore, made or dug on the banks of the *Ashby* canal) navigated thereon, which shall, either before or after, pass on any part of this canal, or the *Oxford* or *Grand Junction*; and a farther sum per ton, equal to the tonnage hereon between Griff and Longford, on all goods which may pass any new communication that may hereafter be opened between the *Ashby* canal and the *Oxford* or *Grand-Junction*; for enforcing which, this company is empowered to erect toll-houses and stop-bars, and place collectors on any part of the *Ashby* canal.

Cree River. The course of this river is nearly north, for 9 or 10 miles of a crooked course, between the counties of Wigton and Kirkcudbright in Scotland; its object is the supply of the adjoining country, and of Wigton, which is a considerable town. It commences in the tide-way in Wigton bay in the Irish or Northern Channel, and terminates at Newton Douglas.

Crinan Canal. Acts 33, 39, and 45 of Geo. III.—The course of this very wide and deep canal is nearly west for about nine miles, in the county of Argyle in Scotland; its sole object is the shortening of the passage for ships be-

tween the Irish Sea and the *Clyde* river (by means of the loch of Fine), by avoiding the voyage round the peninsula of Kintire. It commences at loch Gilp, and terminates in lock Crinan. The rise is 58 feet, and the fall 59 feet, a rivulet near the point of division serving as its feeder. The water in this canal is 12 to 15 feet deep. This line of canal was first surveyed for smaller vessels by Mr. *Watt*, after which Mr. *John Rennie* was employed herein; it appears to have been opened some time, but farther improvements, and the building of a pier in Loch Gilp are yet in hand. The proprietors have been authorised to raise 180,000l., and they have also received 50,000l. of the public money, which parliament granted in aid of this great and important work. The shares are 50l. each. A vessel under sail, not being stopped in proper time, before she arrived at a lock on this canal, bore the same away, and went down therewith into the next pound. A passage may, it is said, be made by means of this canal in three or four days, which frequently took up three weeks. In 1802 the shares herein were 22l. below par.

Cromford Canal. Act Geo. III.—The general direction of this canal is about N.W. for 18 miles, in the counties of Nottingham and Derby; it is considerably elevated: its general objects are the export of coals and of lead, iron, lime-stone, and other minerals from the mines of Derbyshire. Wirksworth and Belper are considerable towns near its course. It commences in the *Erewash* canal at Langley bridge (not far from the junction of *Nottingham* canal therewith), and terminates in the town of Cromford near Matlock. There is a cut to Pinxton coal works of three miles in length, another to Swanwick coal works; also a rail-way branches to Critch lime-works, $1\frac{1}{2}$ mile, and to Biggarlee coal works $1\frac{1}{4}$ mile. From the *Erewash* canal to near Codnor castle, four miles, there is a rise of 80 feet, thence to Cromford, 14 miles, it is level; the Pinxton branch is level, and proceeds from the upper level. The width of this canal at top is 26 feet; the boats are 80 feet long, $7\frac{1}{2}$ feet wide, and $3\frac{1}{2}$ feet deep; when empty they draw 8 or 9 inches of water, and when loaded with 22 tons, they draw about $2\frac{1}{2}$ feet. Near Ripley is a tunnel of 2966 yards in length, which is 9 feet wide withinside at the water's surface, and 8 feet high from thence to the crown of the arch, which is of brick, except some parts where the rock proved hard and sound enough to stand without walling: the side-walls and crown of this arch seem to be part of an ellipsis, but where an inverted or bottom arch was wanted, the same is much flatter. For constructing this tunnel, 33 pits or tunnel-shafts were sunk, some of them on the summit of the hill, being 57 yards deep. This tunnel is said to have cost 7l. per yard in length: it intersects a valuable seam of coals, which is now worked, and in sinking the tunnel-pits excellent iron ore was found, which is now worked, and the furnaces are supplied with coals drawn up through a shaft from below for that purpose. There are several smaller tunnels upon the line for shortening its course. Near Butterly hall there is a considerable deep-cutting, and shorter ones in other places, to avoid the loops round the points of the hills. Over the Derwent river, near Wigwell, there is a large aqueduct bridge 200 yards long and 30 feet high, the river arch is 80 feet span. Two smaller arches by its side serve to carry off floods, and for a road. Over a small river, which comes into the Derwent near Frithly, is another large aqueduct bridge about 200 yards long and 50 feet high; besides the river arch, there are two others, one for floods, and another conveys the turn-pike road under the canal; these two aqueducts are said to have cost about 6000l. There are considerable embankments in some places on this canal. Nearly over the Ripley tunnel there is a reservoir of 50 acres of water when full, the head or embankment of which is 200 yards long, 33 feet in height in the middle of the valley, the base being there 52 yards wide, the top of the bank is four yards wide. This reservoir is said to have cost 1600l.; the mean depth of it is 12 feet, and it will contain about 2800 locks full of water, which is let out by a large pipe and cock in one of the tunnel-pits. There are two other reservoirs for this canal, one of 20, the other of 15 acres. At the Cromford end of the canal there is a considerable stream of water taken in as a feeder, and the whole of the 14 miles of level and branches thereto have their banks made up one foot higher than usual to act as a reserve for dry weather. Mr. *William Jessop* was the engineer to this canal, and it was completed before the year 1794. The total cost is said to have exceeded 80,000l. For the cutting and wheeling of clay, $3\frac{1}{2}$d. per cubic yard, per stage of 20 yards, was usually paid; for gravel $4\frac{1}{2}$d. per yard; for stony ground $4\frac{1}{2}$d. per yard, and 4d. per cubic yard extra for all stones picked out and stacked. In the year 1797, a cut was proposed from the summit-level to the new collieries in Codnor park. In 1801, notices were given for the intended *Belper* canal, that was proposed to join this near to Bull bridge; and in 1802, a cut was proposed to be made from the Derwent aqueduct on this canal to near Dethick, and thence near the Derwent and Wye rivers to the town of Bakewell.

Crouch River. The course of this river is nearly west, in the county of Essex. The principal objects of this navigation are the import of coals, deals, &c. and the export of farm produce, and of oysters from near Walfleet. Billerica and Rochford are the nearest considerable towns to this river. It commences in the English channel (about 10 miles from the mouth of the *Thames*), and terminates at Hull bridge.

Croydon Canal. Act 41 Geo. III.—The general direction of this canal is nearly south for $9\frac{1}{2}$ miles, in the counties of Kent and Surrey: it is not greatly elevated; its objects are the supply of Croydon with coals, deals, &c. and the country through which it passes with manures and other articles, and the conveyance of its produce to the London markets, and the export of fire-stone, flint, and fullers' earth. Croydon is the 108th British town, with a population of 5,743 persons. Deptford is also a considerable place. This canal commences in the *Grand Surry* canal near Deptford (two miles from its connection with the *Thames* at Rotherhithe), and terminates at the new Bason near the town of Croydon. From the *Grand Surry* canal (level with an ordinary high tide in the *Thames*) to the top of Plowgarlic hill, $1\frac{1}{4}$ mile, is a rise of 70 feet, by 12 locks; thence for $\frac{1}{4}$ a mile it is level, and thence for $\frac{3}{4}$ of a mile to the beginning of Forest wood, there is a rise of $79\frac{1}{4}$ feet, by 13 single and one double locks; from thence to Croydon, 7 miles, it is level. The locks upon this canal are 60 feet long and 9 feet wide; each lock has a groove for stop-planks at its head, but no paddle-weirs; the waste water is intended to run over the upper gates. This company are to have a bason for their boats to lie in at Rotherhithe, on the south-east side of the *Grand Surry* entrance bason, and another by the high road near Croydon town. There are seven road bridges and 30 accommodation swing-bridges. On the top and northern slope of Plowgarlick hill, there is a considerable deep-cutting, and others in Sydenham and on Penge common; and near Selhurst wood is a considerable embankment. On Sydenham common there is a reservoir of 10 or 15 acres supplied in wet times by a feeder out of an adjoining vale, and into which its waste or over-fall is to be when full; there is

another reservoir on Norwood common, which, with the long summit-pound on so tenacious a soil, will be sufficient, it is presumed, to supply the locks that are making. At the time the act passed for this canal, it seemed intended to use inclined planes, and to pump the water for supplying the pounds up from the *Grand Surry* canal by steam-engines, that were also intended to wind the boats up the planes: and it seems singular, under these circumstances, that legislative provision was made, for a culvert or small tunnel through Forest-hill for conveying water from the summit-level of this canal on Sydenham common, and by aqueducts or pipes to supply several towns and places with water, viz. by a branch of near $\frac{3}{4}$ of a mile to the top of Dulwich town, and from the end of the said tunnel to Knight's hill by a crooked course of three miles in length through Norwood, and along Knight's hill towards London for one mile; also another branch of near one mile to Streatham town. Mr. *John Rennie* and Mr. *Ralph Dodd* were the engineers, and Mr. *Clark* is now employed as resident engineer thereon. About seven miles of the upper end of this canal is completed and in use, and the remainder is proceeding with great expedition. The company are empowered to raise 80,000l., which is not now expected to prove sufficient; the amount of shares are 100l. each. The sum of 40l. is to be paid annually to the city of London, towards improving the Thames river above London Bridge. This canal is to have its water kept always two feet above the surface of the ground on Croydon common, and some other severe and unprecedented restrictions are introduced in favour of the millers on the Wandle river, at some miles distance.

Croydon and Wandsworth. In September 1800, proposals were made for a canal from the river *Thames* at Wandsworth, following nearly the course of the Wandle river to Croydon in Surry; but the same was given up shortly after, in favour of the north *Surry iron rail-way,* which passes through nearly the same tract.

Cyfarthfa Canal. The general direction of this canal, or *water level,* is nearly N.W. we believe, for about 3 miles, in the county of Brecknock; it is on a high level, and was constructed some years ago by Mr. *Bacon,* to bring coals and iron-ore from the mines in the mountains, to his furnaces at Cyfarthfa, near Merthyr Tidvil. The whole is upon one level, and it does not connect with any other canal or navigation; it is now the property of Mr. *Crawshaw,* the great iron master. It is situate near to the northern ends of the *Glamorganshire* canal and the *Cardiff and Merthyr* rail-way.

Darent River. The course of this river (called Dartford creek,) is south for near 3 miles in the county of Kent; it commences in the tide-way in the river *Thames,* and terminates near the town of Dartford, for whose supply it is principally used.

Dart River. The general direction of this river is nearly N.W. for about 10 miles, in Devonshire; the tide flows through its whole length; its principal objects seem to be the supply of Totness with coals, and the country with shell-sand manure, and the export of farming produce. Dartmouth and Totness are considerable towns; its commencement is in Start bay, and it terminates at the Mill weir, about one mile above Totness; this river is plentifully stored with trout.

Dean-Forest Rail-way. In the year 1802, it was proposed to construct a rail-way from the river *Wye,* near to English Bichnor, we believe, to the summit of the Forest of Dean, its object being the carriage of the immense stores of coal and iron, with which it abounds; Colford is a considerable town near its route. In the preceding year the *Severn and Wye* rail-way was proposed to pass nearly the same track.

Dean River. Act 12 Geo. III.—The direction of this river is nearly S. for about 2 miles, in the county of Nottingham; it is not greatly elevated above the level of the sea; its principal object is the supply of Newark, the 91st town in the list of British population, with 6730 inhabitants. It commences in the river *Trent,* at Crankley's, in South Markham, and terminates at the upper weir near the town of Newark; the works hereon were completed in Jan. 1797. In 1793 the *Newark and Bottesford* was proposed to join this at Newark.

Dearne and Dove Canal. Acts 33 and 40 Geo. III. —The general direction of this canal is about N.W. for $9\frac{1}{2}$ miles, in the West Riding of Yorkshire, its northern end is considerably elevated; its objects are the communication between Sheffield, Wakefield, Halifax, Leeds, Manchester, Liverpool, &c. and the export of the coals and iron-stone, &c. so plentifully found on its course. Barnsley and Rotherham are considerable towns on or near it, so is Doncaster, the 110th town, with 5697 inhabitants. It commences in a side cut of the *Don,* or Dun river, between Swinton and Mexburgh, and terminates in the *Barnsley* canal at Eyming's wood, near Barnsley, there is a branch of $3\frac{1}{2}$ miles to Rockcliff bridge, and another of $1\frac{1}{4}$ miles to Cobcar Ing. From the cut of the *Don* navigation to Knoll Brook the distance is $4\frac{1}{2}$ miles, with a rise of $41\frac{1}{2}$ feet; thence to Aldham Mill, $2\frac{1}{2}$ miles, is a rise of 24 feet, (the Cobcar Ing branch being on its highest level); thence to the *Barnsley* canal is $2\frac{3}{4}$ miles, with a rise of $59\frac{1}{2}$ feet; the Cobcar Ing branch is level; the Rockcliff branch begins from the summit-level, and $1\frac{1}{2}$ mile to Worsborough bridge is level; thence to Rockcliff bridge, $1\frac{3}{4}$ mile, it has a rise of 56 feet. The locks on this canal are built with excellent hewn or ashler stone, and are calculated for boats of 50 or 60 tons burthen, the same as navigate the *Dun* river, and this company are required to keep a depth of water equal to $4\frac{1}{2}$ feet on their lock-sills, and in every part of their line; and for guarding against loss of water on the summit, a stop-gate is to be erected hereon, near the termination in the *Barnsley* canal, and another on that canal below the junction, both of which may be shut and locked when the supply of either canal fails, and it would consume the water of the other. The aqueduct and other bridges hereon are substantially constructed of hewn stone. Tumbling-bays and gauge-weirs are to be erected for supplying several mills. There is a large reservoir near Elsicar. Proprietors of mines may make rail-ways to this canal, if within 1000 yards, or 2000 yards near Wath. Mr. *John Thompson* is said to have been the engineer, and it was completed in the year 1804. The company were empowered to raise 100,000l. The amount of shares 100l. each. The rates of tonnage on this canal are too various and complicate for the room we can allot to this subject, they will be found in *Phillips' 4to. History,* p. 62 to 66; but it must be observed, that the last act (40 Geo. III.) made an increase of, we believe, 50 per cent. on these tolls. Boats are to pay for 6 miles of tonnage, however short a distance they may have navigated on this canal. In May 1797, earl Fitzwilliam proposed, at his own expence, to extend the Cobcar Ing branch to his Elsicar collieries, on being allowed water for the same from the Elsicar reservoir.

Deben River. The course of this river is nearly N.W. for about 10 miles, in the county of Suffolk; its objects are the imports of coals, deals, &c. and exports of farm produce; it commences at the sea near Felixtow, and terminates near Woodbridge, which is a considerable town.

Dee River, (*Aberdeen*). This river takes its course about west for 2 miles, between Aberdeenshire and Mearns county in Scotland, the tide flowing through the whole navigable length; it commences in the harbour of new Aberdeen,

where it is joined by the *Aberdeenshire* canal. New Aberdeen is the 19th town in Britain, with 17,597 inhabitants, and its harbour was improved by a pier of 300 yards in length, begun under the direction of Mr. *John Smeaton*, in 1770, who was employed again in 1778, to make farther improvements. In 1801, Mr. *Thomas Telford* was employed to design new works and improvements hereon, so that ships of 18 or 20 feet draught of water may be accommodated. There are excellent granite quarries near this river.

Dee River, (*Chester*). The general course of this river is nearly S.E. for about 22 miles, in the county of Flint, and skirting the county of Chester: the first 9 miles are by a wide estuary opening to the Irish channel, and from near the town of Flint thereon, a new cut was made for the river up to Chester, under the direction of Mr. *Nathaniel Kinderley*, about the year 1749; before which time the old channel was so choaked with sand, that ships of burthen could not come within 7 or 8 miles of Chester; the new straight cut, that was at first 8 feet deep in general, principally through marshes, soon scoured itself out, so that ships of 200 tons could come up to the town, and where the time of high-water became earlier by $\frac{3}{4}$ of an hour, than when the tide had to make its way through the old crooked and shallow channel. Chester is the 25th town, with 15,052 inhabitants, Holywell near it, is the 111th, with 5,567 persons, and Flint is also a considerable town. On the N.W. side of Chester the *Ellesmere* canal connects with this navigation and crosses it, for which goods pay 2d. per ton to this company; it is also to receive from the *Ellesmere* company whatever its tolls may fall short of 210l. annually. At Chester this river is joined by the *Chester* canal.

Dee River, (*Kirkcudbright*). The course of this river is nearly N. for about 6 miles, in the county of Kirkcudbright in Scotland, being an estuary opening to the Irish sea. Kirkcudbright is a considerable town thereon, and where the *Glenkens* canal connects therewith.

Derby Canal. Act 33 Geo. III.—This canal runs nearly N. for about 9 miles, in the county of Derby; it is not greatly elevated above the level of the sea. Its objects are, the supply of the town of Derby, and the export of coals and iron. Derby is the 43d British town, with a population of 10,832 persons. It commences in the *Trent* river at Swarkstone bridge, crosses and intersects with the *Trent and Mersey* canal, and terminates at Little Eaton, near 4 miles above Derby, from which town a cut of $8\frac{1}{2}$ miles goes off to a place between Sandiacre and Long Eaton, and there joins the *Erewash* canal. There is a *rail-way* branch of $4\frac{1}{2}$ miles, to Smithey-houses near Derby, another to Horsley collieries, and another of $1\frac{1}{4}$ mile to Smalley mills. In case a rail-way, or canal, should be hereafter made S. of the *Trent* from Bredon lime-works, this company has engaged to make a cut between the *Trent and Mersey* canal and the *Trent*, at Weston cliff, opposite thereto. From the *Trent* to the *Trent and Mersey*, $\frac{1}{4}$ a mile, is a rise of — feet; thence to Derby, $5\frac{1}{4}$ miles, is a rise of 12 feet; and thence to Little Eaton, $3\frac{1}{2}$ miles, is a rise of 17 feet; the *Erewash* branch has a fall of 29 feet. This canal is 44 feet wide at top, 24 at bottom, and 5 feet deep, except the upper level next Little Eaton, which is made 6 feet deep to retain the water of wet seasons like a reservoir; the locks are 90 feet long, and 15 feet wide within side: adjoining the town of Derby is a prodigious large weir or tumbling bay, where the canal crosses the *Derwent* river, that was navigable to this place for many years back, but the tolls thereof were expected to fall off on the completion of this canal, and it was therefore agreed, that this company should purchase the whole concern for 3996l. A little W. of the river above-mentioned, the canal crosses a brook in a *cast-iron* trough or aqueduct. This canal was finished in 1794; the company were authorized to borrow 90,000l. the value of shares being 100l. Separate rates of tonnage were fixed on different goods, between the *Trent* and the *Trent and Mersey*, between that and Derby, and on the different cuts and rail-way branches, which are too long for us to insert, they will be found in *Phillips' 4to. History of Canals, Appendix*, p. 55 to 59. Manures are to pass toll-free, and puncheons or clogs of wood, to be used as supports in the adjacent coal-mines, also road materials, except for turnpike-roads; and if the Mansfield turnpike-road tolls are reduced below 4 per cent. on their debt, this company is to make them up to that sum. The profits of this concern are not to exceed 8 per cent. but after 4000l. is accumulated as a stock for contingencies, the tolls are to be reduced. Five thousand tons of coals annually are to pass hereon toll-free, for the supply of the poor of the town of Derby. Horses pay 1d. and cattle $\frac{1}{2}$d. each, for liberty of passing along each rail-way branch.

Derwent River, (*Derby*). The course of this river is nearly N.W. for about 9 or 10 miles, in the county of Derby; its principal object was the supply of Derby, previous to the making of the *Derby* canal, when this concern was sold to that company, as mentioned above. It commenced in the *Trent* river at Wilden-ferry, (where the *Trent and Mersey* canal commences,) and terminated at the town of Derby.

Derwent River, (*New Malton*). The general course of this river is nearly N. for about 37 miles, in the East Riding of Yorkshire; its objects are the supply of New Malton (a considerable town) with coals, deals, &c. and the export of farm produce, chalk, &c. It is but little elevated above the sea; it commences in the *Ouse* river at Barnby, and terminates at the town of New Malton. In January 1804, it was in contemplation to make this river navigable up to Yedingham bridge.

Derwent River, (*Workington*). The course of this river is nearly E. in Cumberland. Workington, on its banks, near the Irish sea, is the 109th British town, with 5,716 inhabitants; to the vicinity of this town there are several *rail-ways*, which bring down coals from Mr. *Curwen's*, and other coal-mines, for exportation from this place.

Devon River. The general direction of this river is nearly N.E. in Clackmannanshire in Scotland, from near Cambus quay, on the Frith of *Forth* (two and a half miles above Alloa) to Medlockfoot. Mr. *John Smeaton* was, in 1765, and again in 1768, consulted, about making this river navigable, or a canal by its side, the rise being $38\frac{1}{2}$ feet, in order to bring down the produce of several coal-mines near its banks, to be shipped on the *Forth*, wherein the spring tides rise 20 feet at Cambus quay. A branch was proposed to Alloa, and another to Sterling.

Dewsbury and Birstal Rail-way. The general direction of this rail-way is nearly N. for about 3 miles, in the West Riding of Yorkshire, and its object is to bring down coals to the vessels in the *Calder* river; it commences in the *Calder and Hebble* navigation at Dewsbury, and terminates at Stubley coal-mines in Birstal parish, which are worked by Messrs. *Thomas Chester* and Sons. who are also the sole proprietors of this iron rail-way, which was completed in the present month (October 1805).

Don, (*or Dun*) River. Act 12 Geo. II. The general direction of this river is nearly S.W. for near 40 miles in the West Riding of Yorkshire, (including what is, in some maps, called the Dutch river, near to the *Ouse*,) the southern end of this navigation is rather elevated. The original objects

of this navigation were principally the supply of Sheffield, and the export of the iron-wares and iron from Sheffield, Rotherham, &c. since which period, the *Dearne and Dove* canal, which joins at Swinton, and the *Stainforth and Keadby*, at Fishlake and at Hangman Hill, and the cut to the *Ayre* river near Snaith, have opened new sources of supply, and for the export of coals, stones, iron, and manufactured goods of several kinds, which this rich track of country produces. Sheffield is the 14th British town, with 31,314 inhabitants, Doncaster is the 110th with 5697 persons; Rotheram, Doncaster, Thorne, and Snaith are also considerable towns on or near this navigation. The commencement is in the *Ouse* river, at Goole bridge, and it terminates at Attercliffe, within 2 miles of Sheffield, and has a cut to the *Ayre*, as above, and side-cuts with locks between Mexburgh and Swinton, and in other places; the tide flows above the junction of the river Went. The *Stainforth and Keadby*, act 33 *Geo.* III. has directed rates for boats passing out of this into that canal by the cut of this river. In September 1803, notices were given, for a new act for weirs and side-cuts to this river in Mexborough, Spotborough, and other places, and a new course for the river, near the junction of Dearne river. And, in February 1803, there was a design of extending this navigation to Sheffield by a canal from Tinsley, 4 miles, for which 30,000l. was subscribed.

Donnington-wood Canal. The general direction of this canal is about N. or N.E. for 7 miles in Shropshire; it is upon a very high level, nearly parallel to the grand ridge on the western side: its object is the conveyance of iron-stone and lime-stone, from the mines to the Donnington-wood iron works in Lileshal parish, and lime and coals for the supply of the town of Newport, which is a considerable place. It commences in the *Shropshire* canal (near its junction with *Shrewsbury* canal,) at Donnington wood, and terminates at Pave-lane wharf near Newport; it has a level branch to Lileshal lime-works, but on a higher level than the line, to which the lime-stone was formerly let down, in boxes through perpendicular shafts, at the same time that other empty boxes were ascending, the construction being nearly the same as the shafts afterwards used at Brierly-hill on the *Shropshire* canal, but like them they have since been disused and inclined planes are now used, on which boxes of lime-stone descend and draw up empty boxes by means of ropes passing over a large drum, to which a brake-wheel is adapted to regulate the motion. The boats hereon carry 25 tons of lading: the canal was cut in 1778 at the joint expence of the marquis of *Stafford* and Messrs. John and Thomas Gilberts. In June 1797 this was proposed to be joined at Pave-lane by the *Newport and Stone* canal.

Dorset and Somerset Canal. Acts 36 and 43 Geo. III.—The general direction of this canal is nearly S. for about 40 miles in the counties of Wilts, Somerset, and Dorset: the middle part of it is on a high level, and crosses the south western branch of the grand ridge. Its principal objects are the supply of the manufacturing towns and neighbourhood through which it passes, with coals from the mines bordering on Mendip, and the opening of an inland communication between the Bristol channel, the *Severn*, the *Thames*, and the southern coast of the island. Froome is the 60th town in the order of population, with 8,748 inhabitants, and Bradford, the 78th, with 7,302 persons; Bruton, Wincanton, Stalbridge, and Sturminster are also considerable towns near the line. The commencement is in the *Kennet and Avon* canal at Widbrook near Bradford, and the termination in the *Stour* river near Gains-cross in Shillingstone-Okeford; from near Froome a branch of about 9 miles proceeds to Nettlebridge collieries in Midsummer-Norton. The Nettlebridge branch was first cut, in order to supply coals to Froome and its neighbourhood; and water being scarce thereon, one of Mr. *Fussel's* balance-locks was erected on a 21 feet fall at Mells near Froome, and was publickly tried on the 6th of September, and 13th of October 1800, and in June 1802, as particularly described in a previous part of this article. An aqueduct bridge was erected several years ago over the river near Froome, but it is with slow pace, we fear, that the works are proceeding towards a final completion. The company were by the first act authorised to raise 225,000l. and a further sum under the second, we believe, the amount of shares being 100l. Stones are to be erected at every half mile: pleasure-boats of 12 feet long and 5 broad may be used on the pounds, 30 yards in width are allowed, in general, for the company to purchase, and 100 yards wide for docks, wharfs, &c. springs may be taken and reservoirs formed any where within 2000 yards of this canal.

Douglas River (*Lower Navigation.*) Acts 6 Geo. I. and 10 and 23 Geo. III. (for *Leeds and Liverpool*). The course of this navigation is nearly south; for 9 miles in Lancashire it is but little elevated above the sea; its objects are the export of common and cannel coals, and farm produce, and the import of lime-stone; it commences in the tide-way in the estuary of the *Ribble* river near Hasketh, and terminates in the *Leeds and Liverpool* canal at Brier's Mill. From the *Ribble* to Solom, about 5 miles, the river Douglas (or Asland) is navigable, and thence to Brier's Mill is a canal 4 miles, with a rise of 8 locks, the whole rise from the *Ribble* being 49 feet. The width of the canal is 24 to 30 feet, and depth of water 5 feet; the locks are 70 feet long, and $15\frac{1}{2}$ feet wide. The first act above authorised Messrs. *William Squires* and *Thomas Steers* to make the *Douglas* river navigable from the Ribble to Miry-lane end, near Wigan, which they effected about the year 1727; being allowed 2s. 6d. per ton for goods, whatever distance they might be navigated thereon; by the first act for the *Leeds and Liverpool* canal (10 Geo. III.), their successors were authorised to make a junction with the *Leeds and Liverpool* canal at Newborough by a cut of $3\frac{1}{4}$ miles long, parallel to this river, with a fall of 12 feet, which they completed in 1774, and the same now forms part of the *Leeds and Liverpool* canal, S.E. of Newborough aqueduct bridge, in consequence of the purchase which that company made of the whole of this concern, in pursuance of their act of 23 of Geo. III.; since which, the canal from Brier's Mill to Solom above described, as part of the lower navigation, was cut and completed in 1781, and the river navigation between Solom and Wigan, 12 or 13 miles (on the upper navigation) has, we believe, been disused since the *Leeds and Liverpool* canal was completed by its side to Wigan, and the communication by the lower *Douglas* navigation to the *Ribble*, above described, was opened.

Dougledge River. The course of this river is nearly north in the county of Pembroke in South Wales, from the tide-way in *Milford-Haven* to Haverfordwest bridge, its object being the supply of that town.

Driffield Canal. Acts 7 and 41 of Geo. III. The course of this navigation is nearly north, for about 11 miles in the East Riding of Yorkshire; it is but little elevated above the sea; its general objects are the import of coals, deals, &c. and the export of farming produce; it commences at Aike-beck mouth in the *Hull* river, and terminates at the town of Great Driffield; the first five miles is by the course of the *Hull* river to Fish-holm clough, and the remaining 6 miles is by a canal; the course of the *Hull* river serves also as a branch of $1\frac{1}{4}$ mile in length to Frodingham bridge. In 1764 Mr. *John Smeaton* was consulted on this intended navi-

gation. In 1804 it was in contemplation to deepen the Frodingham branch, and about 2 miles of the canal up to Snakeholme lock, nearly 2 feet deeper than it was before.

Droitwich Canal. Act 8 of Geo. III. The general direction of this canal is about N.E. for 5¼ miles in the county of Worcester; it is not greatly elevated above the sea; its objects are the export of salt and the import of coals, of which 13,500 tons are annually imported, and used in the boiling of salt, except what the town of Droitwich consumes. It commences in the river *Severn*, at Hawford, and terminates at Chapel bridge in the town of Droitwich; it has a rise of 59¼ feet by 8 locks. This canal was executed by Mr. *James Brindley*, and it is said to present a pattern to canal-makers by the neatness and regularity of its curves, and the stability and excellency of all its works. The proprietors were authorised to raise 33,400l. the amount of shares being 100l. The tonnage on every quarter of grain, or 6 bushels of meal, is 2d. and on every ton of salt, coals, or other matters, 1s. 6d. By the act for the *Worcester and Birmingham* canal (31 Geo. III.), the shares herein are guaranteed to produce 5 per cent. annually, and are to be made up by that company in case of their falling below that sum. Owing to the overflowings of the copious salt springs near Droitwich, this canal presents the curious spectacle of a salt-water canal, in the interior of the country, in which no river-fish can live.

Dromreagh Canal. This is a canal in Ireland, concerning which our information extends no further, than that the parliament of that country, between the years 1768 and 1771, granted 3000l. of the public money towards carrying on the works.

Drumglass Canal. This is a canal connecting with the Drumglass collieries in Ireland, towards the works of which canal, and those collieries, the parliament of that country, between the years 1753 and 1771, granted no less than 117,714l. of the public money!

Dudley (*and Owen*) Canal. Acts 16, 25, 30, 33, and 36 of Geo. III. The general direction of this canal is nearly N.W. by a crooked course of 13 miles in Worcestershire, a detached part of Shropshire, and Staffordshire; it is situate very high, its two ends are on the eastern side of the grand ridge, while its middle, by means of two very long tunnels, is on the western side of the same. Dudley is the 49th British town with a population of 10,107 persons, and the busy and rich country through which this canal passes, furnishes an ample tonnage in the export of coals, iron, and lime, while its communication with the *Stourbridge* canal, by the Black-Delph branch, and the terminating canals, occasions a very considerable carrying trade thereon. This canal commences in the *Worcester and Birmingham* canal at Selly Oak, and terminates in the old *Birmingham* at Tipton Green; from near Dudley there is a branch of 2 miles to the *Stourbridge* canal at Black-Delph in Kingswinford, there is another branch of 1¼ mile to near Dudley town, and a branch from this last of ¾ of a mile to Dudley coal-works. From the *Worcester and Birmingham* canal to the Black-Delph branch, 10½ miles are level, thence to near the entrance of the Dudley tunnel, about ¾ of a mile is a rise of 31 feet by 5 locks, thence through the tunnel it is level, and from thence, in the last ½ of a mile, is a fall of 13 feet by 2 locks, to the old *Birmingham* canal: the Black-Delph branch has a fall of 85 feet by 9 locks to the *Stourbridge* canal; the Dudley branch has a rise of 64 feet in the first ¼ of a mile, the remainder thereof being level, and the colliery branch level therewith. The depth of water in this canal is 5 feet; the width of the locks on the Black-Delph branch is 7 feet. To near Lapal, or Laplat, this canal passes through a tunnel 3776 yards long, at Gorsty hill it passes through another of 623 yards, under a collateral branch of the grand ridge, and at Dudley there is another tunnel of 2926 yards in length on the summit-level of the canal; the arch of this last tunnel has a height of 13½ feet. At Cradley-pool is a large reservoir for supplying the lockage of the Black-Delph branch. It is provided, that level cuts may be made from this canal towards any coal-mine, to the extent of 2000 yards. A stop-lock is erected at the junction with the *Worcester and Birmingham* canal, by which either company has a power of preventing the other from drawing off their head of water. The Black-Delph branch was first executed, which was then united with the Dudley part of the canal which had been constructed by lord viscount Dudley and Ward; these were completed and in use before the extension or main length, to Selly Oak was designed. The company has been authorised to raise 229,100l. the amount of shares being 100l. each originally. Owing to the different acts under which the parts of this canal were progressively undertaken, the rates of tonnage being different thereon, and to the variety of rates on different articles, we cannot attempt an account thereof in this short abstract, they will be found in *Cary's Inland Navigation*, p. 53 to 55, also p. 43, where certain rates are made payable to the old *Birmingham* company on account of the junction therewith, (but which have since been varied by the 34 of Geo. III. for *Birmingham* canal) and at p. 70. will be found other rates, in consequence of the junction with the *Worcester and Birmingham* canal. In the *Stratford* act (33 Geo. III.) are several regulations relating to tolls on goods passing to or from this canal; and this company are bound to make up the profits of the *Stourbridge* canal to 12l. per share annually, but not exceeding 3l. on each share.

Durham and Chester-le-Street. In February 1797 Mr. *Robert Whitworth* made a report in favour of a proposed canal from the *Tyne* to Chester-le-Street, and thence to Durham, it was estimated to cost 79,000l. and the probable advantage thereon to subscribers was stated to be near 20 per cent. Durham is the 74th British town, with 7,530 inhabitants; this country abounds in coals.

Eden River. The general direction of this river is nearly S.E. for about 12 or 13 miles in the county of Cumberland; its principal objects seem the export of coals, and the supply of Carlisle, which is a considerable town. It commences in the tide-way of the *Solway* Firth, and terminates at Carlisle bridge. In 1795, the *Newcastle and Carlisle* canal was proposed to join this river at Carlisle. In 1799 a *rail-way* from the earl of Carlisle's coal-works, near Brompton, to this river, was opened; and in 1803 another was intended from lord Lowther's coal-works at Warnel, about 11 miles distant from Carlisle.

Edinburgh and Glasgow Canal. This canal, projected about the year 1796, appears to have nearly a west direction for about 50 miles in the counties of Edinburgh, Linlithgow, and Lanark in Scotland; its objects are the export of coals and lime from Clydesdale, through which it passes, and the opening of a direct communication between Edinburgh and Glasgow. Edinburgh (and Leith) being the 3d British town, with a population of 82,560 persons, and Glasgow the 5th, with 77,385 inhabitants; from the scanty materials to which we have at present access, it seems that this canal commences in the tide-way of the *Forth*, in the harbour of Leith, and terminates in the tide-way of the *Clyde*, in the town of Glasgow, and was finished in 1802; that at Glasgow it connects with the *Monkland*, and in 1803 the *Glasgow and Saltcoats* was proposed also to join it.

Eil and Shiel canal. In the year 1803 Mr. *Thomas Telford*

surveyed this line of canal, being a length of 3 miles from the tide-way in Loch *Eil* within some miles of the west end of the *Inverness and Fort-William*, or Caledonian canal, to Loch Shiel, a fresh-water lake on the Highland coast of Scotland; Loch Shiel was found $7\frac{7}{12}$ feet higher than Loch *Eil*, and in order to conduct a 12 feet deep canal out of the former to the shore of the latter, it appears that deep cutting will be required, for about a mile to the depth of $47\frac{1}{2}$ feet, there being no water on the summit to supply a lockage up and down.

Ellesmere Canal. Acts 33, two of the 36, 41, 42, and 44 of Geo. III.; the general direction of this canal is nearly south for 57 miles, by a crooked course through the counties of Chester, Flint, and Denbigh, (North Wales) and Salop; its principal summit is considerably elevated above the sea; its great object is said to be the improvement of the agriculture of the extensive and fertile tracts, through which it passes, for uniting the *Mersey*, *Dee*, and *Severn* rivers, and exporting coals, lime, and slate, from the skirts of the Welsh hills. Liverpool is the 4th British town, with a population of 77,653 persons, Chester is the 25th with 15,052 persons, Shrewsbury the 36th with 14,739 persons, and Ellesmere the 112th with 5,553 persons; Wrexham, Whitchurch, and Oswestry, are also considerable towns on or near this canal or its branches. This canal commences in the *Mersey* river (9 miles above Liverpool) at Ellesmere-port in Netherpool, and terminates in the *Severn* river at Bagley bridge, very near to the termination of the *Shrewsbury* canal, to which it is proposed to be joined; at the N.W. part of Chester city, it connects with the *Chester* canal, and near the same place crosses and connects with the tide-way in the *Dee* river; from near Pulford a branch of 4 miles is proposed to Holt; from near Gwerselt a branch of — miles to Talwern coal-works in the parish of Mould, near the head of the Cegedog valley, where there is an opportunity of constructing a reservoir of 82 acres to supply the same (this branch to pass Frood collieries, Brumbo iron-works, and Nant-y-frith lime-works); another short cut from Gresford to Allington; and a *rail-way* branch to Ruabon-brook; and to the river Dee at Llandinillo; from near Pont-Cysylty, a branch to Acresair coal-works; from Franston common, is a branch of about 25 miles passing the town of Whitchurch, to the *Chester* canal at Stoke in Acton parish near Nantwich; from which branch, another of about 7 miles proceeds from Fen-Moss to Prees Heath; from Hordley on the main line, a branch of near 11 miles proceeds to the line of the *Montgomery* canal near Llanymynech, and the Verniew river; there being from this branch another to the termination of the *Montgomery* canal at Portywain lime-works near Llanyblodwell, and another short one is intended to Marda bridge near Oswestry. From the *Mersey* to the *Dee* (sometimes called the Wirral branch) the distance is 8 miles; from the *Dee* river to the Brumbo or Talwern branch it is $11\frac{1}{2}$ miles, with a rise of 380 feet; thence along the summit pound, and through the Chirk tunnel $8\frac{1}{2}$ miles are level; thence to the north end of the great iron-aqueduct, $\frac{1}{4}$ a mile, is a fall of 75 feet; thence to St. Martins moor, 9 miles, it is level; thence to the Whitchurch branch at Francton-common, $2\frac{3}{4}$ miles, is a fall of 13 feet; thence to the Llanymynech line at Hordley is $\frac{1}{4}$ of a mile with 33 feet fall; thence to Ormond park, $14\frac{1}{2}$ miles, is level; and thence to the *Severn* river at Shrewsbury is 2 miles with a fall of 107 feet. The Holt branch is level, the Whitchurch branch to that town, 14 miles, is level, and thence to the *Chester* canal, 11 miles, has a fall of 128 feet; the Prees Heath branch is level, the Llanymynech branch, 12 miles, has a fall of 19 feet. The depth of water in this canal is $4\frac{1}{2}$ feet, and the canal in general is calculated for boats of 70 feet long and 7 wide; but the Wirral branch is formed for boats of 70 feet long and 14 feet wide. There is a tunnel near Chirk of 775 yards in length, and another at Weston-Lullingfield of 487 yards in length. At Pont-Cysylty, this canal is carried over the river Dee in an immense aqueduct trough, composed of cast-iron plates, 20 feet wide, 6 feet deep, and 320 feet long; this is supported on 19 pair of conical stone pillars at 52 feet asunder, and the middle ones 125 feet in height! at Chirk is a very large stone aqueduct bridge of 10 arches, 200 yards in length and 65 feet high, over the Ceriog river; and over the Allen river there is also an aqueduct bridge. This canal is fed from the Dee river by the Llandinillo branch, and that river is compensated by a cut from Bala-pool, and, all springs within 2 miles of this canal may be taken for its use. Near Ruabon, one of *Rowland and Co.*'s balance locks was, in 1797, tried on a 12 feet fall for saving water, as before mentioned. The engineers employed on this extensive work, were Messrs. *William Jessop*, *Thomas Telford*, — *Fletcher*, and *Thomas Dadford*; the most considerable progress was first made at the northern end of the line, and in February 1796, flatts laden with coals began to arrive at Chester from the Lancashire collieries by the Wirral branch, and soon after convenient passage-boats were established, for the regular conveyance of passengers towards Liverpool or back, at lower rates than is charged on *Bridgewater*'s canal, according to distance. In January 1797, the navigation was continued to Beeston brook; and in the same year the southern end of the line was opened from Shrewsbury to the Weston-Lullingfield tunnel. The immense aqueduct at Pont-Cysylty was in hand in 1804, and was more than half completed before the end of that year, as was also the stone aqueduct at Chirk. The company are authorised to raise 500,000l., the amount of shares being 100l., which it seems were, in 1802, at 20l. below par. The rates of tonnage are, for coals, culm, limestone, lime, and salt, $1\frac{1}{2}$d. per ton per mile; for free-stone, timber, slate, iron-stone, lead ore, iron, and lead, 2d., and for all other goods 3d. per ton per mile, except road materials and manures (but not lime) upon the pounds, or when the water flows waste over the lock-weirs. On crossing the *Dee* river at Chester, goods pay 2d. per ton to the Dee company, and their tolls are guaranteed to the amount of 210l. annually. While this canal was projecting, a rival scheme was started, called the Eastern Grand Trunk from the *Severn* at Shrewsbury to the *Chester* canal at Crow's nest, with cuts to Vable-Cruis, to Bonham-Furnace, Holt, and other places.

Erewash Canal. Act 17 Geo. III.—The general direction of this canal is nearly north for $11\frac{3}{4}$ miles along the skirt of the county of Derby, near to Nottinghamshire; its northern end is considerably elevated above the level of the sea; its chief object is the export of coals from the numerous collieries on its banks, and those on the banks of the *Nutbrook* canal which joins it at Stanton, and the *Nottingham* canal which joins it near Langley Bridge; the branch of the *Derby* canal joins it between Sandiacre and Long Eaton, and the *Trent* canal near Sawley. It commences in the *Trent* river near Sawley (opposite nearly to the *Loughborough* navigation, or Soar river,), and terminates in the *Cromford* canal at Langley Bridge, the rise being $108\frac{3}{4}$ feet; there is an iron *rail-way* branch to Brinsley coal-works, on which an experiment was, as before related, made about the year 1800, on the load which one horse could draw both up and down the declivity. By the act of 33 of Geo. III. for *Derby* canal, a reduction of the rates between the junction therewith and the *Trent* river was made, conditionally, that no other junction be made between this canal and Derby, but the present one near Sandiacre; and by the 34 of Geo. III. for *Trent* river, the annual rent of 5l. is commuted for a toll of 6d. on every laden boat which shall cross the *Trent* between the

Soar river and this canal. A reservoir belonging to the *Nottingham* canal has a gauge-sluice, which furnishes a regular and daily supply of water to this canal. The first survey for this line of canal was made in the year 1776.

Eske River, (*Montrose*). This river is navigable but a short distance in the tide-way from the German Ocean to the town of Montrose, in Angus county in Scotland. Montrose is the 67th British town, with 7,974 inhabitants.

Eske River, (*Whitby*). The navigable part of this river is but short, in a S.W. direction in the East Riding of Yorkshire: it commences at the German Ocean, and extends to Whitby bridge. In 1765 Mr. *John Smeaton* was consulted about clearing this river and the harbour of Whitby, of the shail or refuse ore, from which alum had been manufactured, and whereby the harbour had become in time nearly choaked up. Whitby is the 75th British town, with a population of 7,483 persons; within a few years past, a pier has been built with free stone, under the direction of Mr. *John Rennie*, for the improvement of the mouth of this harbour.

Exe River. The course of this river is nearly N.W. for about 10 miles in the county of Devon; its principal object seems the supply of Exeter and Topsham; near Topsham it is to be joined by the *Grand Western* canal. It commences in the English Channel at Exmouth, and terminates at the city of Exeter, which is the 21st town in Britain, with 17,398 inhabitants: from Exeter it was in 1800 proposed to continue the navigation to Crediton; and in 1769, the *Exeter and Uphill* canal was proposed to be made from the same place.

Exeter and Crediton. In the year 1800 it was proposed to make the rivers Exe and Credy navigable, from Exeter city to the town of Crediton, about seven miles, above Exeter quay on the river *Exe*.

Exeter and Uphill. In 1769 Mr. *John Brindley* surveyed the country for a canal from the river *Exe* at Exeter, by Tiverton, Wellington, Taunton, and Glastonbury, to the British Channel near Uphill; the objects of which have been since embraced in the *Grand Western* canal.

Fergus Canal. This is one of the Irish inland navigations, in aid of which, public money was from time to time granted, though in the present instance we are told that it amounted to no more than 85l.

Forth River, (*or Firth*). This principal river of North Britain has its course nearly west for about 70 miles between the counties of Fife, Haddington, Edinburgh, Linlithgow, Stirling, Perth, and Clackmannan, the first 33 miles being a very wide estuary, the next 18 miles are still of considerable width, and the last 13 miles next Stirling are remarkably crooked. An immense general trade is carried on upon this river, and for the supply of the metropolis of Scotland, assisted by the *Edinburgh and Glasgow* canal, that joins it at Leith, the *Burrowstowness* at that town, the *Forth and Clyde*, or great canal at Grangemouth, the *Caron* river near Rothkennar, and the *Devon* river near Cambus Quay. Edinburgh (with Leith) is the 3d British town, with 82,560 inhabitants, Dumferline is the 52d, with 9,980 persons, and North Berwick, Crail, Anstruther, Dysart, Kirkaldie, Kinghorn, Bruntisland, Inverkeithing, Musselburgh, Queen's-Ferry, Burrowstowness, Linlithgow, Falkirk, Culross, Clackmannan, Alloa, and Stirling, are also considerable towns on or near this fine river. It commences in the German Ocean, and terminates at Stirling bridge, and is navigable for ships through a great part of its course; at Cambus Quay the spring tides rise 20 feet, but below this there are sands called the Thrask Shallows, concerning the removal of which, Mr. *John Smeaton* was consulted in 1767. In 1801, the channel south of Inch-keith isle was deepened, to enable ships to approach Leith harbour more safely and readily. Leith harbour has undergone great improvements of late years under the acts of the 28, 38, 39, and 45 of Geo. III., by the last 25,000l. of the public money was granted for the wet-docks and other works which have been carrying on there under Mr. *John Rennie*, since the laying of the foundations, 14 May 1801. Methel harbour on the north side of the *Forth* is also under improvement, and by the 45 of Geo. III., 2,000l. of the public money was granted towards the building of the pier there. In the year 1767, Messrs. *Watt* and *Morison* surveyed the upper part of the *Forth* river, and proposed to extend a navigation from Sterling bridge to the slate and lime quarries in Aberfoil, on which the opinion of Mr. *John Smeaton* was also taken.

Forth and Clyde Canal. Acts 8, 13, and 24 of Geo. III.—The general direction of this great canal is nearly west for 35 miles, in the counties of Stirling, Dumbarton, and Lanerk, in Scotland: it crosses a low part of the grand-ridge between the tide-ways of the east and west seas; its principal object is a communication between those important rivers, the *Forth* and the *Clyde*, and between the northern metropolis, and the great manufacturing towns of Glasgow, Paisley, &c.; near to Grangemouth the *Burrowstowness* canal joins it. Glasgow is the 5th British town, with a population of 77,385 persons, and Falkirk the 59th, with 8,838 inhabitants. Kirkintulloch and Dumbarton are also considerable places near the line. This canal commences at Grangemouth harbour in the *Forth* river, and terminates at Bowlings bay near Dalmuir-Burnfoot, in the *Clyde* river. There is a cut of 2¾ miles to the town of Glasgow, where it joins the *Clyde* river, the *Monkland* canal, and the *Edinburgh and Glasgow* canal; and it was in 1803, proposed to join the *Glasgow and Saltcoats* canal; there is another cut with a lock into the *Caron* river at Caron-shore, near the great Caron iron-works. From low-water in the *Forth* in Grangemouth lock, N° 1, to lock N° 20, 10¼ miles, is a rise of 165 feet; thence to lock N° 21, the summit-level is 16 miles, and thence to low water in the *Clyde* at Bowling's bay lock, N° 39, is a fall of 156 feet; the width of the canal is 56 feet at top, and 27 at bottom, and the depth of water 8 feet; each lock is 75 feet long, and 20 feet wide in the clear, and vessels of 70 or 80 tons are used. This canal is crossed in 33 places by draw-bridges, has 33 culverts or arches under it, and 10 large aqueduct bridges; that over the Kelvin is 400 feet in length, and 70 feet high above the surface of the river, (see *figs.* 19, 20, and 21, *Canals*, *Plate* II.) and there is a large aqueduct which crosses the turnpike road from Glasgow to Stirling at Kirkintulloch. At Kilmananmuir is a reservoir of 70 acres extent, and 22 feet deep at the sluice; and near Kilsyth is another of 50 acres, 24 feet deep for supplying the summit-level of this canal. In Bowlings-bay, and near the Kelvin aqueduct, are dry-docks, and other conveniences for repairing of vessels and boats. Mr. *John Smeaton* was first employed to survey this line in 1764, and he laid the present design, and executed a considerable part of the eastern end before 1775, when the work stood still for some years, after which, Mr. *Robert Whitworth* was called in; he completed the remainder, and it was opened with great solemnity on the 28th of July 1790. The design of a canal between the *Forth* and *Clyde* has been at times entertained ever since the reign of Charles II., and besides the above engineers, since the year 1723, Messrs. *Gordon*, *Mackell*, *Watt*, *Brindley*, *Golborne*, *Thomas Yeoman*, &c. have been consulted or employed. The canal was first made to commence in the *Caron* river, about a mile from its mouth, but was afterwards continued into the *Forth* at Grange-

mouth harbour. The proprietors were authorifed in their firft act to raife 200,000l. in 100l. fhares; after which, 50,000l. of the public money was granted to aid the work; in 1783, 212,000l. had been expended, and no dividend or intereft had been paid on the fhares. The rate of tonnage is 2d. per ton per mile on all kinds of goods, except lime and lime-ftone, which is to pay ½d., and iron and iron-ftone 1d. per ton per mile, while road-materials (except lime-ftone) and manures are to pafs toll free. For unloading or loading of Britifh or Irifh veffels in Grangemouth harbour, 1d. per ton is to be paid, (by 24 Geo. III.) and for foreign veffels 2d. per ton. Rafts of fir timber are allowed to be floated upon this canal and pafs the locks, thefe often contain 70 tons each. An accident is related of a veffel coming down from the weftward on this canal, when the wind blew ftrong from that quarter, and not being ftopped in time at one of the locks, fhe bore down the gates, and went down fuddenly into the pound below. In December 1801, a veffel conftructed by Mr. *Symington*, (as already defcribed) was tried on this canal for dragging or towing boats, by the operation of a fteam-engine; to the head of this veffel ftampers were applied, that could be worked by the engine for breaking ice, when the canal is frozen over.

Foss-dyke Canal. The general direction of this navigation is nearly S.E. for 11 miles, in the counties of Lincoln and Nottingham; it is upon one level, not much elevated above the fea, though a great diftance from it, and prefents the curious inftance of a canal difcharging its wafte water into one river (the *Witham*,) while flood-gates are neceffary at the other end, to keep out the waters of the other river (the *Trent*); its object is a communication between thefe two rivers, for fupplying coals and exporting farm produce. Lincoln is the 76th Britifh town, with a population of 7,398 perfons. This canalcommences in the *Trent* river at Torkfey, and terminates in Brayford meer, a natural pool in the *Witham* river, near Lincoln. It has a lock at Torkfey, conftructed on the principle of a fea-lock, that is capable of penning the water into the canal, or out of it, according to the circumftance whether the *Trent* or it may be the loweft; between Brayford meer and Lincoln highbridge, a hard of gravel or fhallow, called Brayford head, held up the water in this canal, to about 2½ feet deep, which otherwife would, in dry times, have been emptied into the Witham, too low for navigation. Mr. *John Smeaton* and Mr. *John Grundy* were confulted in 1762, and the former engineer again in 1782, when he recommended raifing the banks of this canal to obtain a better depth of water, cutting off its connection with the Witham by a pound-lock, and fupplying it with water by an aqueduct or feeder, from a refervoir to be made near the Witham, fouth of Brayford meer. We are not acquainted with the date when this canal was firft dug or made navigable; Mr. Ellifon's wharf thereon, near its eaft end, was, it appears, built about 1742.

Foss Navigation. Acts 33 and 41 Geo. III.—The direction of the *Fofs* river, which this navigation follows, is nearly N. by a crooked courfe of about 13 miles, through the North Riding of Yorkfhire: its elevation is not very great above the level of the fea; its objects are the fupply of the city of York, the import of coals for the ufe of the adjacent country, and to effect a better drainage of the fame. York is the 23d Britifh town, with 16,145 inhabitants. This navigation commences in the *Oufe* river at the city of York, and terminates at Stillington mill. It is fed by a refervoir on Oulftone moor: it appears that the corporation of York were by a licence of king *Richard* II. required to erect and maintain proper bridges over this river. This company were authorifed to raife 45,400l. the amount of fhares being 100l. each. The rates of tonnage will be found in *Phillips' 4to. Hiftory, Appendix*, p. 81 and 82; and in the laft act, by which an additional 1½d. per ton, on heavy articles, were impofed, and by which the proprietors were authorifed to proceed no higher than Sheriff-Hutton bridge with their works, until the neceffary funds were accumulated to proceed with the remainder of their line. Some years ago, a pleafure-boat, made wholly of fheet iron, was tried on this navigation, 12 feet long, and capable of carrying 15 perfons, and yet fo light that two men could carry it.

Glamorganshire Canal. Acts 30 and 36 Geo. III.—The general direction of this canal is nearly N.W. for 25 miles, in the county of Glamorgan in South Wales. Its objects are the export of the produce of the immenfe iron, coal, and lime works in the neighbourhood of Merthyr Tidvil, &c. and the fupply of the rapidly increafing population thereof; at Eglwyfila the *Aberdare* canal joins, and the *Cardiff and Merthyr* rail-way runs by its fide, and joins it at thofe two places. Its northern end is confiderably elevated. Cardiff and Caerphilly are confiderable towns on or near the line; it commences in a fea-bafon, or dock, in the *Severn*, at the Lowyer-layer near Cardiff, and terminates near the town of Merthyr; it has a *rail-way* branch from Merthyr to Dowlais iron works. From the tide-way at Lower layer to Merthyr is a rife of near 600 feet, and during a part of this diftance the canal fkirts precipitous mountains at the height of near 300 feet above the river Tav or Taaff, which it clofely accompanies through its whole length. The floating dock at Lower-layer is 16 feet deep, in which a great number of fhips, of 300 tons burthen, can lie conftantly afloat, and load or unload, either at the fpacious warehoufes on its banks, or from, or to, the boats belonging to this canal, or the trams ufed on the *Cardiff and Merthyr* rail-way, that here commences. There is a large aqueduct bridge over the Tav near Gallygare. This company were authorifed to raife 100,000l. and to the powers for raifing the laft 10,000l. this fingular condition was annexed, viz. that the whole concern fhould be completed within two years, after which no further money fhould be applied, except for repairs. At Merthyr there is a famous water-wheel, made of caft-iron, 50 feet diameter, at Mr. Crawfhaw's works; the water being conveyed thereto for a great diftance in an iron aqueduct.

Glafgow and Saltcoats. In May 1803 the line of country between the *Clyde* river at Ardroffan, near Saltcoats, and the *Clyde* river again at Glafgow (paffing Paifley and connecting with the *Cart* river) was furveyed by Mr. *John Rennie*; in 1805, the fubject was revived, and met the fupport of the earl of Eglingtown and many others, coupled with the defign of building a pier on a ledge of rocks near Caftle Craigs, and forming wet-docks, &c. to be called Ardroffan harbour, for which an application was made to parliament in the fame year. At Glafgow this canal would connect with the *Forth and Clyde*, the *Monkland*, and the *Edinburgh and Glafgow*: the line thereof is through a country rich in coals and lime-ftone.

Glenkenns Canal. Act 42 Geo. III.—The direction of this canal is firft N.E. and then N.W. for about 27 miles, in Glenkenns, in the county of Kirkcudbright in Scotland: it is not very greatly elevated; the object of it is the export of the coals, iron-ftone, lime, and other minerals with which the country abounds; Kirkcudbright and New Galloway are confiderable towns near the line. It commences in the tide-way in the *Dee* river at Kirkcudbright, and terminates in the boat-pool at Dalry. There is provifion made for branches to the neighbouring mines and rail-ways, and inclined planes may be fubftituted, inftead of a canal and locks in any part. The company is authorifed to

raise 45,000l. the shares being 100l. each. but it is provided, that the works are not to commence until 20,000l. is subscribed, and that within five years, or the powers of the act are to cease; water may be taken from within 2000 yards of the line, except certain streams used for irrigation.

GLOUCESTER AND BERKLEY CANAL. Acts 33, 37, and 45 Geo. III.—The general direction of this canal, one of the largest in England, is nearly N.E. for 18¼ miles, in the county of Gloucester; it is but very little elevated above the sea; its object is to shorten the navigation for ships by a serpentine course of 28 miles on the *Severn* river, between Berkley and Gloucester; near Wheatenhurst it crosses and unites with the *Stroudwater* canal; Gloucester is the 72d British town, with a population of 7,579 persons; Berkley is also a considerable place. This canal commences with a sea-lock in the *Severn* river at Berkley-pill, and terminates in a grand and capacious bason, connecting with the *Severn* river at Gloucester, it has a short branch to a new wharf at Berkley town, and another of about 2 miles in length to the *Severn* river at Hock-crib in Arlingham; the whole is on one level with tide-locks at its connecting points with the *Severn* to preserve its water at one constant height. This canal is 70 feet wide, and 15 or 18 feet deep in water, and the locks, &c. thereon, are capacious enough to admit ships of 300 tons burthen to pass! The company are authorised to raised 200,000l. in 100l. shares. The tonnage varies on different sized vessels, and is too long for us to insert, the particulars will be found in *Phillips' 4to. History, Appendix*, p. 83 and 84. Unforeseen difficulties have attended the execution of this wide and deep canal, by intersecting a hard rock for great distances in the level meadows, where no such thing was expected. Some immensely large slips have happened in the banks, and the walls of the Gloucester bason slipped in, notwithstanding the land-ties which had been provided; the upper end of the canal, for several miles, has been finished; in 1797, it was said that only 6 miles remained to be cut; and we hope, that the act of last sessions will be the means of speedily completing the whole. Mr *Haskew*'s machine, calculated to assist in excavating a canal, was here tried in 1796, as before mentioned.

Gloucestershire Rail-way. In the year 1804 it was proposed to construct a rail-way from the *Avon* river at Bitton below Bath to Sodbury coal-works in Gloucestershire, with branches to Pucklechurch, Haul-lane, Coal-pit-heath in Westerleigh, Smith's tynings, and other collieries, in order to bring their produce to Bath and Bristol, and for the consumption of the interior of the country, by means of the *Kennet and Avon* canal.

GRAND CANAL, (*Ireland*). This canal was commenced, we believe, soon after the year 1753, but we have not the dates of the earlier acts; since the union there was one passed, the 43 Geo. III. The general direction of this canal is nearly west, for 61½ miles through Dublin, Kildare, and King's Counties, in Ireland; it passes a low part of the grand ridge of Ireland, on the Bog of Allen. Its objects are the supply of Dublin with coal, &c., the varied produce of the banks of the *Shannon*, and opening an inland communication through the country. It commences in a grand bason in James-street, Dublin (which connects with the *Liffey* river and the new *Docks*), and terminates in the *Shannon* river, at Tarmonbury, near Moy's Town: it has collateral branches to the *Boyne* river at Edenderry, to the *Barrow* river at Monestraven, and also at Portarlington; there are also branches to Naastown and to Johnstown. This canal is, we believe, 5 feet deep, the locks are 80 feet long and 16 wide, in the clear, and are built of hewn stone; it has employed the attention of various engineers, among whom are mentioned, Messrs. *Omes, Vallency, John Trait, William Jessop*, &c. In the year 1770 this canal had proceeded from Dublin into the Bog of Allen, when, owing to mismanagement, it stood still for several years, and it was not until the beginning of 1804 that the whole line was finished and opened. The sums of the public money which have been granted by the parliaments to aid this work are immense; between 1753 and 1771 they amounted to 78,231l. It has been proposed to reduce the tolls or tonnage since the opening of this canal. In the beginning of the present year (1805) it was proposed to continue a branch from this canal, near Athy, for 9 miles, to the foot of the Doonane Hills, in Queen's county, and thence to tunnel two miles into the hill, to drain the rich veins of coal therein, and bring out their produce.

GRAND JUNCTION CANAL. Acts 33, 34, three of the 35, 36, 38, 41, 43, and two of the 45 Geo. III.—The general direction of this canal is nearly north-west for 90¼ miles, in the counties of Middlesex, Hertford, Buckingham, Bedford (a very small distance), and Northampton. It has a summit of considerable height near Tring, which it passes without a tunnel; and near its northern end it crosses the grand-ridge by a tunnel. Its principal objects are, a communication between the metropolis and the various canals of the midland counties, the supply of coals, deals, slate, &c. to the several towns on the line and branches, and the export of the agricultural products, lime, flints, &c. of the country through which it passes; at Northampton it joins the *Nen* river by a *rail-way* branch, and the same is intended there also to join the *Leicestershire and Northamptonshire Union* canal. London, as is well known, is the first town in Britain for population, with 864,845 inhabitants, and Northampton is the 85th, with 7,020 persons; Brentford, Uxbridge, Rickmansworth, Watford, St. Albans, Hemel-Hempstead, Berkhampstead, Tring, Wendover, Aylesbury, Leighton-Buzard, Fenny-Stratford, Newport-Pagnel, Stoney-Stratford, Buckingham, Towcester, and Daventry, are also considerable towns on or near this canal or its branches. The commencement of this canal is in the river *Thames*, near the extremity of the tide-way at Brentford creek, and its termination in the *Oxford* canal at Braunston. From Bull bridge a branch, 13½ miles in length, goes to Paddington, one of the environs of London; to the town of Rickmansworth, there is a cut of about ¼ of a mile, with a lock at its entrance; from Bulbourn head a branch extends for 6¾ miles to Wendover; from Cosgrove a branch of 1¼ mile extends to Stoney or Old Stratford, and thence 9½ miles further to Buckingham; and from Gayton a *rail-way* branch of 5 miles extends to the river *Nen*, and the intended termination of the *Leicestershire and Northamptonshire Union* canal at Northampton. To Watford a branch of 2 miles, and thence about 8 miles farther to St. Albans, has been surveyed and provided for in the acts; another to Aylesbury of about 6 miles, and another to Daventry of 1½ mile in length, but these last are not executed. From the *Thames* at Brentford to Two-waters is 28½ miles, with 268 feet rise; thence to Cowroast is 7¼ miles, with a rise of 127 feet; thence to the Wendover branch is 3¾ miles, of the highest summit-level; thence to the crossing of the Ouse river, between Wolverton and Cosgrove, is 25¼ miles, with a fall of 192 feet (this being the lowest place); thence to Stoke Bruern is 6¼ miles, with a rise of 112 feet; thence (through the Blisworth tunnel) to the south end of Whitton parish, 13½ miles, is level; thence to Whitton mill, in Long Buckby, ⅜th of a mile, is a rise of 60 feet; thence along the summit-level, and through Braunston tunnel to its north end, 4¼ miles, is level; and thence to the *Oxford* canal at Braunston, near 1 mile, is a fall of 37 feet. The Paddington branch is level (at about 90 feet above the *Thames*, and 48½ feet above the Strand-pavement at Exeter-

change). The Wendover branch is level, and connects with the Bulborne or Tring summit pound: the Buckingham branch has a rise of 15 feet; the Northampton branch has a fall of 120 feet, and the cut to Daventry is to have a rise of 60 feet. The width of the main line is 36 feet at top, about 24 feet at bottom, and 4½ feet deep in water: the Wendover branch is 28 feet wide at top, 18 at bottom, and 4½ feet deep; and the Buckingham branch is only 20 feet wide at top, 10 at bottom, and 4½ feet deep in the general. The Northampton rail-way, which is now (October 1805) nearly or quite finished and ready for opening, is of iron, and double, that is, has two roads for the carriages going different ways. The locks on the line are 86 feet long, 15 feet wide in the clear, and rise about 7 feet each on the average, requiring about 9030 cubic feet, or 250 tons of water to fill them each time that a barge passes. On the line there are 101 locks, besides the 9 spare ones in Wolverton-valley; on the Buckingham branch there are 2 locks. Two kinds of vessels are in use upon this canal, barges with square heads and sterns, and flat bottoms, that carry 60 tons, and boats with sharp ends, or nearly so, of half the width, that carry 25 tons. At White-friars, just above Blackfriars-bridge, on the *Thames*, this company built extensive warehouses, over a dock, in which barges lay afloat from one tide to the next; these are now let to Mr. *Pickford*, the great waggon and boat-master. At Paddington a spacious bason or straight cut, 400 yards long and 30 wide, has been formed with wharfs at its head, and others are daily extending westward along its sides; behind this, on the north side, is a spacious yard for a vegetable and a hay and straw market, with immense sheds, under which loads of those articles can stand in the dry when it rains; and on the south side pens are erected and provision made for a large cattle market. The number of wharfs erected on this extensive line and its branches by individuals are too great for us to attempt to particularize them. The number of culverts or small water-courses under the canal and its branches are very great. And on the towing path there are a number of large and high wooden bridges for crossing the entrances to branches, docks, or over streams of water; for some distance from Paddington provision is made under the bridges for a towing path on each side of the canal. The tunnel between Stoke-Bruern and Blisworth (already described), is 3080 yards in length, 15 feet wide, and 19 feet high, at 60 feet below the top of Blisworth hill, through which it penetrates. Braunston tunnel, between that place and Daventry, is 2045 yards in length: another tunnel was at first intended near King's-Langley for avoiding Cashiobury, and other parks in the Colne valley; but an agreement was afterwards come to with their owners for a passage through them, instead of tunnelling. Between Cow-roast and Bulbourne there is an immense deep-cutting for passing the great range of chalk-hills near Tring; this extends for 3 miles, and is 30 feet deep in the highest part; near Dawley there is a great length of deep-cutting through the immense bed of gravel at that place; at the ends of the Blisworth tunnel, and at several other places there are also deep-cuttings. Between Wolverton and Cosgrove a stupendous embankment, with three aqueduct arches under the same, has been constructed, since the locks were made for crossing the Ouse river, as above mentioned, over which the canal has, since August 1805, been conducted, and by which 4 locks on the south side of the valley, and 5 locks on its north side, are avoided, except a lock of 18 inches rise, near the north end of the embankment, by which 12 miles in length of level pound is held up (on the line and Buckingham branch), and separated from 10 miles of level pound south thereof, to beyond Fenny-Stratford town, (where another lock of only 18 inches rise occurs, to hold up a pound of some miles in length that was intended, but for a mistake in the levelling, to have been in one pound); this embankment is ½ a mile long, and 30 feet high, where it crosses the Ouse. At Weedon-Beck, and at Bugbrook, there are also most stupendous embankments, and river and road aqueduct-arches, and many lesser embankments and aqueduct bridges occur on the line and branches; those over the Brent river, and over Bays-water on the Paddington branch are considerable. On Harefield Moor there is a very wide and large piece of water on the canal: others at Great Berkhampstead, at Halton park, and two other places on the Wendover branch. Five considerable reservoirs have been constructed for preserving water for this canal, or the mills, whose streams have been diverted for its use; that at Aldenham covers 68¼ acres, at Willstone is one of 40 acres, and those at Weston-Turville, Braunston, and Daventry, are also of very considerable dimensions. The principal feeder for the southern summit is at Wendover, and there are others at Little Tring, Tring, and Miswell (the last being arched over for ¼ of a mile). The middle and lower part of the line is supplied by a feeder at Soulbury, and the northern summit is supplied by a feeder from Watford, near Daventry; besides which, that summit has had its banks raised to accumulate an extra depth of water in wet times, and a steam engine has recently been erected for pumping up the water out of the level of the *Oxford* canal to that summit, that is let down therefrom by the lockage. At Little Tring an engine was, in June 1803, erected for pumping the water collected in Willstone reservoir into the Wendover branch of the southern summit-level; and at Nash mill, some distance below Two-waters, in the Colne valley, an engine is now erecting to return the lockage water of 4 locks that are there placed near to each other. On the south and north sides of the Tring summit, several pairs of side ponds have been lately added to the locks, for saving part of their consumption of water. Where the Towceller river (the Tove) is crossed and joined there are very considerable weirs or tumbling-bays, and others on the old course, in the Wolverton valley; and, between Great Berkhamstead and Uxbridge, these are continually occurring, owing to the canal having unfortunately been conducted into and through almost every mill-dam in that distance: overfalls of less size are also very common on every part of the line, so are stop-gates, trunks, and every other necessary appendage and convenience to a navigable canal. Mr. *William Jessop* was the engineer to this extensive concern; Mr. *James Barnes* and Mr. *John Holland* were employed in executing different parts of the works, on which Mr. *Thomas Telford* was lately employed to report his opinion; since 1803 Mr. *Benjamin Bevan* has been employed in repairing the leaky parts, constructing side-ponds, &c. in the middle district of this canal. The works on this canal commenced at both of its extremities, soon after the passing of the first act; and the tunnel at Braunston being completed, the navigation was opened, in July 1796, as far southward from the *Oxford* canal, as the great embankment at Weedon Beck; in June 1797, the same was extended to the next great embankment at Bugbrook; and about November in the same year, to the north end of the intended tunnel at Blisworth. Beginning at the southern end in the *Thames*, the navigation to Two-waters was completed in June 1798, and in June 1801 the branch therefrom to Paddington was opened; in the year 1799, the canal was completed to Bulbourne, and the branch therefrom to Wendover; in June 1800, it was extended to Fenny-Stratford; and about October 1800 to the south end of the intended tunnel at Blisworth; at the same time a double iron *rail-way* of near 3¼ miles in length (since removed) was laid across Blisworth

Hill, to connect the two parts of the canal, and form the much wished for grand junction; in May 1801, the branch to Buckingham was opened; it was not until March 1805 that the Blisworth tunnel was completed, and the navigation of the whole line opened; and, lastly, in August 1805, the immense Wolverton embankment was opened for improving the same, and avoiding 8 locks, but which locks still remain by its side, as a reserve, in case of accident, to this immense mound of earth, or the three large arches under it. This company were authorised by their first nine acts to raise 1,528,000l. to which their first act of last session made a considerable addition; and it is feared that the expenditure will altogether exceed two millions sterling! The shares are of 100l. value each, which have at some periods of the business sold as high as 210l., and at others have been down at 65l.! Shares in this concern are allowed to be split into such small portions among different holders, as ⅛th or 12½l. each. On the original shares no dividend or interest has yet been received, but now as the tolls amount to full 7,000l. per month, it is hoped a dividend will begin to be made. Inland coals from the rich and inexhaustible mines with which this and other canals form direct communications, were forbid under severe penalties (although two legislative attempts to enforce the same proved inefficient) to be brought nearer to London than the N.W. end of Grove park in Hertfordshire, until the last act of the late session mentioned above, by which 50,000 tons of such coals are allowed to be brought to Paddington in the current year, on paying a duty equivalent to that paid in the *Thames* on sea-brought coals. The market at Paddington, after an ineffectual and most extraordinary opposition from the city of London, was opened in May 1802, for the sale of fat cattle, hay, straw, corn, vegetables, &c. By the act 41 Geo. III., this company was authorised to lay pipes in certain streets in Paddington, Mary-le-bone, &c. for supplying the inhabitants with water; but at that time, certain millers, whose dams the line had been made to pass through, were not consulted. In June 1801, packet-boats were established, that continue to pass regularly at stated hours during most of the year, for the conveyance of passengers and parcels between London and Uxbridge; and for some time after the opening of the Buckingham branch, a boat went regularly between Paddington and that town; but the number of passengers and parcels were found inadequate to support the expence of such an establishment. Trading boats are not allowed to pass along upon this canal except in the day time, unless such as have a special licence from the company for such purpose. Mr. *Pickford* has a great number of boats, which proceed as regularly day and night upon this canal, and the other canals north of it, as the mail-coaches do on the roads, although with less expedition. A common trading boat has been known to arrive at Paddington in 63 hours from Coventry. In December 1799, the experiment was first tried, of bringing fat Oxen to London in boats by means of this canal. The rates of *tonnage* on this canal were at first very low, as will be seen in *Phillips'* 4to. *History*, *Appendix*, p. 91. Additional tolls were provided in the 43d of Geo. III. for passing the Blisworth tunnel and Woolverton embankment; and by the first act of the last sessions (45 Geo. III.), the rates on the whole line and branches were varied, and increased for short distances. The act of the 33d provided certain rates, which are to be paid to the *Oxford* company (See *Phillips' Appendix*, p. 93.) for goods passing thereon to or from this canal, and this company is bound (since the beginning of 1804), to make up the same to the amount of 10,000l. per annum. This company is also bound to pay annually to the city of London the sum of 600l. for the liberty of making a junction with the *Thames*; and all goods passing into or out of the same on this canal are to pay ½d. per ton, to be applied towards improving the middle navigation of the *Thames* river. The intended cut to Aylesbury was, on account of the scarcity of water at Marsworth, where it was to join the line, changed for a rail-way, and in the year 1803, the same was begun; the iron rails were actually purchased, and brought to the spot, but, alas! in one of those reverses of favour to which borough towns are ever liable, the work was stopped, the rails were ordered to be sold, and years may now perhaps elapse before Aylesbury is permitted to enjoy the advantage of a canal or rail-way communication. About the year 1793, an extension of the Rickmansworth branch of this canal was proposed to the town of Chesham. In 1793, and again in 1802, it was proposed to extend a branch from near Slapton to the foot of Puddle-hill between Dunstable and Hockliff; one object of which was the export of the valuable white freestone from the quarries at Tottenhoe; this object may, however, it is presumed, be obtained without such cut; and stone of equal quality be got in several places on the summit branch. In the year 1802, the country westward of Uxbridge was surveyed by Mr. *John Holland*, with the intention of extending a branch of this canal from below Cowley lock, (continuing the level of the Paddington water) to the *Thames* at Harleford in Great Marlow parish; it was also proposed, after crossing and uniting with the *Thames* at this place, to extend this branch, by a rise of three locks, to a side-cut of the *Kennet* river at St. Giles's in Reading, with a branch therefrom to the *Thames* at Sunning: the objects of this branch were, a more direct communication with the Bristol channel, by means of the *Kennet and Avon* canal, the supply of the country bordering on this canal and its branches with peat manure from near Reading, the better supply of, and communication with London, by means of a canal without a lock, between the *Thames* at Great-Marlow, and Paddington, the gaining from the *Thames* that supply of water, which had been denied from the Colne for the intended water-works, and the lockage of the *London* canal; which was, in 1802, proposed to extend from the bason of this canal at Paddington to the *London Docks*, and thereby to communicate with the *Thames*; after which a *rail-way* was, in the same year, proposed to extend from Paddington over nearly the same ground. It was before 1773 that a canal was first proposed from Paddington to Uxbridge, nearly in the route of the line now accomplished; and in 1773, Mr. *James Sharp* proposed an extension of this to the *Kennet* river. In June 1803, a survey was taken for extending the intended Aylesbury branch by Tame to the *Thames and Isis* navigation, and *Wilts and Berks* canal near Abingdon. And in the same year, the *Leicestershire and Northamptonshire Union* canal was proposed to be joined to the line of this canal at Long-Buckby wharf near Daventry, instead of joining its Northampton branch at that town.

Grand Surry canal. Act 41 Geo. III.—The general direction of this canal is nearly S.W. for about 12 miles, by a crooked course in the county of Surry, and through a small part of Kent. It is not greatly elevated in any part: its objects are the supply of the neighbourhood through which it passes with coals, deals, manures, &c. the bringing of vegetables, and other articles for the supply of London: forming a communication between three points of the *Thames* river, and with the *Croydon* canal, which it joins near Deptford. It commences in the river *Thames* at Wilkinson's gun-wharf in Rotherhithe, and is to terminate at the town of Mitcham; near Walworth a branch of about ¾ of a mile goes off to join the *Thames* at

Vauxhall creek by Cumberland gardens. There is to be a cut of near $1\frac{1}{2}$ mile to Horsemonger lane; another of $\frac{1}{2}$ a mile to Peckham; another of one mile to But-lane Deptford; another of $\frac{1}{4}$ of a mile to his majesty's victualling office and the dock-yard at Deptford, and another of $\frac{1}{8}$ of a mile into Greenland dock, by which it will again communicate with the *Thames* river.

From the river *Thames* to the junction of the *Croydon* canal the distance is 2 miles, and nearly level with high water in the tide-way of the *Thames*, at which height the water is to be held up by tide or entrance locks; thence to the Vauxhall branch at Kennington common it is 3 miles and level; thence to Brixton-causeway, $1\frac{3}{4}$ mile, it has a considerable rise; thence to the proposed Kingston branch, $4\frac{1}{2}$ miles, it is level; and thence to Mitcham town it is $\frac{3}{4}$ of a mile: the Vauxhall, Horsemonger-lane, Peckham, But-lane, King's yard, and Greenland-dock branches, are all level. This canal is calculated for wide or river boats: near the commencement, at Wilkinson's wharf, a large bason is designed, and a smaller one at But lane near the Greenwich road: across Rushey-green to Brixton-causeway an inclined plane is intended. Mr. *Ralph Dodd* was, we are told, the contriver of this canal, and under his directions the works were begun, and considerable progress made between Rotherhithe and the Peckham branch; but for more than two years past, little further progress appears to have been made. The company were authorised to raise 60,000l. in 100l. shares. The tonnage on this canal varies from 2d. to 6d. per ton per mile on different kinds of goods. The company are to pay a rent of 60l. per annum to the city of London for communicating with the *Thames* river. Collateral cuts to the extent of 1500 yards may be made by consent of the land owners. In 1800, it was intended to extend this canal $6\frac{1}{2}$ miles further to the *Thames* river on the south side of the town of Kingston, which was to pass the *Surry iron rail-way* at Merton abbey, by an aqueduct bridge 11 feet high in the clear, and the Wandle river by another 15 feet above its surface; from Norbiton common this was intended to branch again to the town of Epsom, $5\frac{1}{2}$ miles, and from Mitcham the canal was there also proposed to be extended to the town of Croydon. In the same year there was also a proposal for extending the intended Kingston branch to the *Wey* river (near the commencement of the *Basingstoke* canal), as part of one of the lines between *Portsmouth and London*. The *Croydon* canal company are to have a dock or bason for their boats by the side of this canal near the *Thames* at Rotherhithe; which, with the entrance lock and bason of this canal, are now excavating, and seem on a scale calculated for small ships.

Grand Western Canal. Act 35 Geo. III.—The general direction of this canal is nearly N.E. for about 35 miles, in the counties of Devon and Somerset: it crosses the south-western branch of the grand-ridge; its objects being a connection between the southern coast and the Bristol channel, the supply of the country with coals, deals, &c. and the export of farming produce. Exeter is the 21st British town, with a population of 17,398 persons; Wellington is the 73d, with 7,531 persons; Tiverton the 94th, with 6,505 persons, and Taunton, the 106th, with 5,794 persons; Topsham, Bradninch, and Cullumpton, are also considerable towns near this line; which commences in the tide-way of the river *Exe* at the town of Topsham, and terminates in the *Tone* river at Taunton bridge; it has a cut of about seven miles to Tiverton, and other short ones to Cullumpton and Wallington. It is provided, that the brick bridges shall not have a rise of more than $2\frac{1}{2}$ inches in a yard on the ascent of the road over them. Two reservoirs are to be made in the valley of the Culm river, and two in the river Tone valley. Springs within 2000 yards of the line may be taken, and cuts to any place within five miles may be made by consent of the land owners. The company are authorised to raise 330,000l., the amount of shares being 100l. each. We have not been able to learn that any progress is yet made in the cutting of this canal, although one through this line of country has been so long desired, as appears by Mr. *Brindley*'s survey for the *Exeter and Uphill* canal, that was proposed in the year 1769.

Grantham Canal. Acts 33 and 39 of Geo. III.—The general direction of this canal is nearly east, by a crooked course of $33\frac{3}{4}$ miles, in the counties of Nottingham, Leicester, and Lincoln: its eastern end is rather elevated. Its objects are the supply of Grantham and the neighbourhood through its course with coals, lime, deals, &c. and the export of farming products. Nottingham is the 17th British town, with 28,861 inhabitants; and Grantham the 85th, with 7,014 persons; Bingham is also a considerable town. This canal commences in the *Trent* river, near Holme-pierpoint, (almost opposite the *Nottingham* canal, to the *Trent* canal, and to the town of Nottingham,) and terminates at the town of Grantham; there is a branch of three miles in length to the town of Bingham. From the *Trent* river to Cropwell-bishop, $6\frac{1}{2}$ miles, is a rise of 82 feet; thence to Stainwith-closes, 20 miles, is level; thence to Woolsthorpe point, $1\frac{3}{4}$ mile, is a rise of $58\frac{1}{2}$ feet; and thence to Grantham, five miles, is level: the cut to Bingham is level. This canal, which is through a clayey district, is wholly supplied by reservoirs, of which, one at Denton is 20 acres, and nine feet deep, for supplying the head-level; and that at Knipton for receiving the flood waters of the Devon river, was 60 acres, and nine feet deep, and in 1804, the bank or head of this last was raised four feet higher. The company were authorised to raise 124,000l., the old shares being 100l. value each, and the new shares (200 in number) 120l. each. The tonnage on all goods passing to or from this canal and the *Trent* river is to be $2\frac{1}{2}$d. per ton, and $1\frac{1}{2}$d. per ton per mile for navigating on this canal: manures and road materials to pass toll free, except lime-stone, which is to pay $\frac{3}{4}$d. per ton per mile. The *Newark and Bottesford* canal was at this time (1793) in contemplation to join this near Stainwith; and the tolls for entrance therefrom, or on goods passing into that intended canal, were settled in the first act above. The profits to the proprietors of this canal are limited to a dividend of 8 per cent. per annum, and after 3,000ls. are collected and deposited as a fund, the above tolls are to be lowered, as much as circumstances will admit. The *Trent* river proprietors are to take certain tolls on goods passing into or out of this canal to the *Nottingham* canal, in consequence of their deepening the river near the entrances to these canals; and goods passing from this canal on the *Trent* are not to be liable to their new rates of 34 Geo. III. unless they pass on the *Trent* canal, to be made under that act above Nottingham.

Gresley's Canal. Act 15 Geo. III.—The direction of this canal is about N.W., and level, in the county of Stafford: it is situate very near to the grand-ridge on its eastern side. Its objects are the supply of the town of Newcastle under-line with coals from Apdale collieries, and the export of coals from the mines to the west of it, by means of the *Newcastle under-line Junction* canal, which now joins it at each of its ends. This canal was constructed at the sole expence of sir Nigel *Grisley*, bart., who was bound by the act, for 21 years after 1775, to supply the inhabitants of Newcastle with coals at 5s. 6d. per ton of 2,400lb. or $3\frac{1}{2}$d. by the single cwt. (of 120lb.); and during the following term of 21 years, their price was not to ex-

ceed 6s. per great ton. In 1796, the *Commercial* canal was proposed to connect with this canal at each end, as the *Newcastle under-line Junction* afterwards did in 1798.

Grimsby Canal. Act 36 Geo. III.—This canal has a S.W. direction for $1\frac{1}{2}$ mile, in Lincolnshire: it is one of the largest cuts in England, and calculated to admit ships of 700 to 1000 tons burthen. It commences in the tide-way in the *Humber* river near its mouth, and terminates in the spacious wet-dock in Grimsby harbour. The lock to this canal is 126 feet long, 36 feet wide, and the walls are 27 feet high; the cost of it, we are told, was 14,000l. besides the piling for the foundation, although bricks were delivered there at 18s. 6d. per thousand, and stone at 8d. per cubic foot. The depth of water in this canal is 20 feet: it was constructed under the direction of that able engineer Mr. *John Rennie*. In the year 1804, three acres more surface was excavated in addition to Grimsby wet-docks, and the same was re-opened, after a temporary interruption, on the 24th of July.

Hamoaze River. This river, or rather estuary, has nearly a north course for about nine miles, between the counties of Cornwall and Devon on their southern coast: it is frequented by the largest ships of the royal navy. Plymouth is the 9th British town, with a population of 43,194 persons; Plympton-Earle and Saltash are also considerable towns near this estuary, which commences in Plymouth sound near Cawsand bay, and terminates in the river *Tamar*, near St. Mellion. Near Warley the *Tavy* river falls into it; and Cat-water, Sutton-pool, and Stone-house creek, are branches from this estuary. In 1767, Mr. *John Smeaton* was consulted about a new bridge and causeway over Stone-house creek. In 1801, it was in contemplation to build a pier from Pinlee point for the better security of ships lying in Cawsand bay from the E.S.E. winds. By an act of 45 of Geo. III. 4,000l. of the public money was voted towards cleansing and deepening Cat-water and Sutton-pool; and it is now in contemplation to construct a floating-dock in Sutton-pool capable of holding 100 merchants' ships always afloat.

Hampton Gay and Isleworth Canal. In the year 1792, a canal was proposed, to take a course nearly N.W. for about 60 miles, in the counties of Middlesex, Buckingham, and Oxford; commencing in the *Thames* river at Isleworth, and terminating in the *Oxford* canal at Hampton-Gay. It was intended to effect that junction between the metropolis and the midland canals, which the *Grand-Junction* now accomplishes: it was to pass the chalk hills by a tunnel at Wendover, and to have a cut of three miles to Aylesbury.

Hartlepool Canal. This is only a very short cut of 300 yards in length, on the coast of Durham, from the sea into Hartlepool harbour: it was cut in the year 1764, at the expence of sir John H. *Duval*, through a solid rock, to the great depth of 19 feet. In 1796, Mr. *Ralph Dodd* proposed, we are told, some improvements of this harbour.

Haslingden Canal. Act 33 of Geo. III.—The general direction of this canal is nearly north for 13 miles, in the county of Lancaster; it is considerably elevated, crossing the Haslingden and Liverpool branch of the grand-ridge. Its objects are the export of the rich stores of coal, lime-stone, &c. on its course, and a communication between Manchester and the *Leeds and Liverpool* canal. Bury is the 84th British town, with a population of 7,072 persons; Haslingden is also a considerable town. It commences in the *Manchester Boulton and Bury* canal at Bury, and terminates in the *Leeds and Liverpool* canal at Church. No locks are to be built on this line, except by consent of three-fourths of all the millers who occupy the streams of water; it is intended to erect inclined planes. The company are authorised to raise 87,600l.; the amount of a share is 100l. The tonnage upon all kinds of goods which do not pass a lock or inclined plane, $1\frac{1}{2}$d. per ton per mile; coals, or other mineral products, are to pay 2d., and timber, goods, wares, &c. 3d. per ton per mile, if they pass any lock or plane. Road materials (except for turnpike roads), and all manures, except lime, are to pass free on the levels, and through the locks when water runs waste over their weirs. Passage-boats are to be specially licensed by the company instead of paying tonnage. No wharfage is to be charged at the public wharfs, unless on goods remaining there above three weeks. We do not understand that much progress is made towards the completion of this canal.

Headon and Paul Canal. It is now (1805) in contemplation to form a canal from the *Humber* river at Paul to the town of Headon in Holderness, about three miles in the east riding of Yorkshire: its objects are the supply of Headon with coals and other articles, and the export of agricultural products.

Hereford and Gloucester Canal. Acts 31 and 33 of Geo. III.—The general direction of this canal is nearly N.W. for $35\frac{1}{2}$ miles, in the counties of Gloucester and Hereford; the middle part of this canal is considerably elevated. Its object is the export of coals from the neighbourhood of Newent, and of the cyder and agricultural products of the country. Gloucester is the 72d British town, with a population of 7,579 persons; and Hereford, the 89th, with 6,828 inhabitants. Newent and Ledbury are also considerable towns on this line. It commences in the tide-way of the *Severn* river at Gloucester, crosses Alney Isle, and another branch of the *Severn* to Lassington, and terminates near the *Wye* river at Bysters-gate in Hereford; it has a short cut to Newent. From the *Severn* to Ledbury the distance is 18 miles, with a rise of $195\frac{1}{2}$ feet; thence to Monkhide is $8\frac{1}{2}$ miles on the summit-level; thence to Withington marsh it is three miles, with a fall of 30 feet; and thence to Hereford, six miles, it is level. Newent cut is level. On this line are three considerable tunnels, that at Oxenhal is 2192 yards in length; at Cannon-Frome is one of 1320 yards; and near Hereford, another of 440 yards in length. Mr. *Joseph Clowes* is the engineer; in July 1796, this canal was finished, from the *Severn* to Newent, and in March 1798, the Oxenhall tunnel was finished, and the navigation extended to Ledbury, and coals were in consequence reduced in price at that town from 24s. to 13s. 6d. per ton! The company were authorised to raise 55,000l. The prices of work in 1794, on this canal, 4d. per cubic yard for stages of 20 to 25 yards of wheeling: wheel-barrows were not used for moving stuff to greater distances than 100 yards; puddling cost 6d. per cubic yard. The rates of tonnage are for coals 2d. per ton per mile; for manures, bricks, and rubble stone, lime or clay, 1d. per ton per mile; corn, meal, hewn stone, hops, wool, and other goods, 3d.: there are also particular rates for certain parts of the canal. The cut across Alney Isle, owing to the tide of the *Severn*, entering it from each end, and dropping its sediment in the middle, is very liable to choak with mud. Springs or streams of water within 3,000 yards of the line may be taken for the use of this canal.

Hereford and Lydbrook. In 1802, it was proposed to construct a *rail-way* from the *Wye* river near the bridge in Hereford to join the same river again opposite to Lydbrook.

Heyl River, (or *Hale.*) The course of this river or rather estuary is nearly south for two miles, in the county of Cornwall, on its north-eastern coast: it commences in *St. Ives* bay, and terminates at the town of St. Erth: it is navigable only for small vessels, being almost choaked at the entrance of the bay. In 1766, Mr. *John Smeaton* was consulted on the building of a north-east pier at the entrance of St. Ives bay; the spring-tides here rise 26 feet.

Horncastle Navigation. Acts 32 and 40 of Geo. III.—The general direction of this navigation is nearly N.E. for about 11 miles, in the county of Lincoln; it is not much elevated above the sea: its objects are the supply of Horncastle and its neighbourhood with coals, deals, &c. and the export of agricultural products. Horncastle and Tattershall are considerable towns on this line. It commences in the old *Witham* river near Tattershall, and occupies the site of Dyson's and Gibson's former cut to Tattershall, passing that town to Horncastle by the course of the Bain river. The company were authorised to raise 45,000l., the amount of each share being 50l. The dividends are not to exceed 8 per cent.; but after 1000l. is accumulated as a fund for contingencies, the tolls are to be lowered, to keep the profits within that limit. The first rates of tonnage are given in *Phillips's* 4to. *History, Appendix*, p. 24, but these were varied and increased by the last act above. This company purchased the old Tattershall canal, and were, by their first act, to contribute jointly with the *Witham* and *Sleaford* companies in the expences, during the next seven years, in improving and deepening the course of the *Witham* between Lincoln high-bridge and the *Fosse-dyke* canal, in order to facilitate the passage of goods to and from the *Trent* river, and in consequence, but half the accustomed *Witham* dues were to be paid for goods passing to and from this navigation. In September 1802, this navigation, and the bason at Horncastle, were completed and opened.

Huddersfield Canal. Acts 33 and 40 of Geo. III. The general direction of this canal is south-west for 19½ miles in Yorkshire and Lancashire; it crosses the Grand-Ridge, at a great elevation, by one of the longest tunnels in this kingdom, in a rocky mountain: its objects are the carrying of coals that are found towards both its extremities, the supply of part of the country with lime, the conveyance of farming produce to the great towns, and the forming of a more direct communication between Hull and Manchester and Liverpool. Huddersfield is the 81st British town, with a population of 7268 persons: Ashton under-line is also a considerable town. This canal commences in Sir John *Ramsden's* canal near Huddersfield, and terminates in the *Manchester Ashton and Oldham* canal, at Duckenfield Bridge, near the town of Ashton-under-line (near which the *Peak-Forest* canal also joins it). From *Ramsden's* canal to Marsden the distance is 7¼ miles, with a rise of 436 feet; thence and through the tunnel to near Saddleworth it is 4 miles, and level; and thence to the *Manchester Ashton and Oldham* canal, 8¼ miles, is a fall of 334 feet. The lock at the entrance from *Ramsden's* canal is 8 feet wide, this canal being only intended for narrow and long boats. The Tunnel through the Stannage Hills near Marsden is to be three miles in length, near to which, on the summit-level, the company are authorised to make reservoirs to contain 20,000 lock-falls of water, (each 180 cubic yards), and may make others if these prove insufficient. About the year 1798, that part of the line between Huddersfield and Marsden was completed and opened; in the same year the head of a large reservoir near Marsden broke, and the torrent of water let down thereby did considerable damage to the country below it. The company are authorised to raise 274,000l., the amount of shares being 100l. These became greatly depreciated in value, about the year 1800, owing principally, it is supposed, to many of the original subscribers not being able to answer the calls for money, by which the works were retarded, and the canal remained in an unproductive state: the Tunnel under the Stannage Hill is now proceeding. The rates of tonnage are from ½d. to 3d. per ton per mile for different goods, (see *Phillips's* 4to. *History, Appendix*, pp. 135, 136.) besides which 1s. 6d. per ton is to be paid extra, on all goods which pass through the tunnel; less lading than 15 tons is not to pass any lock, unless the water runs waste thereat, without consent; no rates are to be taken by Sir John *Ramsden* for the goods which pass between his warehouses at Huddersfield and this canal, this company to amend and keep that part of his canal in repair, in consequence, and are to guarantee his tolls not being lessened, taking an average of three years before this canal is cut. This company is also bound not to make any branch or extension of the canal to any other navigation to the eastward; but, in such case, the tolls thereof are to be divided between *Ramsden's*, the *Calder and Hebble*, and *Ayre and Calder* proprietors, instead of being taken by this company.

Hull River. The course of this river is nearly north for about 12 miles, in the East Riding of Yorkshire; it is but very little higher than the sea: its objects are the supply of Beverley and the adjacent country with coals, deals, &c. and the supply of Beverley and Hull with farm produce. Kingston-upon-Hull (or Hull) is the 16th British town, with 29,516 inhabitants; and Beverley is the 100th, with 6001 persons. This navigation commences in the tide-way of the *Humber* at Hull, and terminates in the *Driffield* navigation upon the same river at Aike-beck mouth. In Leven parish (between Eske and Leven-bars) this is joined by the *Hull and Leven* canal.

Hull and Leven Canal. Acts 41 and 45 of Geo. III. The course of this canal is nearly east for about three miles, in the East Riding of Yorkshire; it is in a very low situation; its objects are the supply of Leven town, of lime to the country east of it, and the export of the agricultural produce thereof for the supply of Hull and Beverley. It commences in the *Hull* river, and terminates at Leven bridge. Mrs. *Charlotte Bethel* is the sole proprietor of this canal, on which Mr. *John Rennie*, Mr. *William Jessop*, and Mr. *James Creassy* were consulted. This canal was finished some time ago; and the act of last session was for raising the tolls, which were found disproportionate to the expence of its construction and management.

Humber River. Act 23 Henry VIII.—This noble river, or rather estuary, has nearly a west direction for about 40 miles between the counties of York and Lincoln. The tide flows with great rapidity through its whole length, and the depth of water is sufficient for ships of considerable burthen, which trade in vast numbers to the port of Hull, and with the numerous eastern rivers which connect with it. Hull contains, as above stated, 29,516 inhabitants; and Barton is the 96th British town, with 6197 persons. Grimsby, Pattrington, Headon, and Burton are also considerable towns on or near to this river. It commences in the German Ocean at the Spurn Head, and terminates in the *Ouse* and the *Trent* rivers, at their junction at Trent-fall: it is joined at its mouth, near Tetney, by the *Louth* river; at Grimsby, by the Grimsby canal and docks; at Kingston-upon-Hull, by the spacious Hull docks and by the *Hull* river; in Wintringham, by the *Ancholme* river; and at Foss-dyke Clough, near Flaxfleet, by the *Market-Weighton* canal. The port of Hull, and the accommodations of this river, have been greatly improved, by the constructing of

wet-docks at Hull; the acts 14, 42, and 45 of Geo. III. having passed for these purposes, the first dock was opened in September 1778. In 1803, the new Humber-dock was proposed, from Myton-gates to Hessel-gates, on the site of the old ramparts, to form seven acres of water, to which a 50 gun ship may have access from the *Humber*, and 70 sail of ships may lie constantly afloat, to be surrounded in part by spacious warehouses. By the act for the same, 30,000l., in 100l. shares, was to be raised; these shares have since borne a premium of near 50 per cent. The act of the late session was for raising more money to complete this vast undertaking, now in great forwardness. In September 1802, a small dock was begun on the shore of the *Humber* for market and ferry boats; a number of dolphins or floating buoys were, about the same time, placed on the banks of the river. In 1774, Mr. *John Smeaton* was employed to build two light-houses on the Spurn Head, at 300 yards apart, which, in June 1776, were in imminent danger of having their foundations undermined by a great storm: in September 1803, the lowest of these light-houses was burnt down by accident. Coal-ships, passing the *Humber*'s mouth for the London market, pay 1d. on each chaldron of their cargo, towards the support of these lights. In 1800 it was in contemplation to erect a light-house at Stallingborough, on the south shore of the *Humber*. In 1802 the *Cottingham and Hull* canal was proposed, to connect with this river at Hull; in the same year, the *Keyingham-Level* navigation was proposed to join at Stone-creek. In 1805 the *Headon and Paul* canal was proposed to connect with it at Paul.

Idle River. The course of this river is nearly west for about 10 miles, in Nottinghamshire: it commences in the *Trent* river at Stockwith, (near to the termination of the *Chesterfield* canal,) and terminates at the town of Bawtry. At half a mile from the *Trent* is Misterton sas or sluice, with an opening of 17¾ feet, and two lock-doors 16 feet high, opening towards the *Trent*, to keep the floods thereof out of the low lands through which this river passes. In 1764, Mr. *John Smeaton* was consulted on this navigation and drainage.

Inverness and Fort-William Canal. Acts 43, 44, and 45 of Geo. III.—This grand or *Caledonian* canal, as it is sometimes called, has nearly a south-west direction for 59 miles, in Inverness and Argyle shires, in the Highlands of Scotland; it passes the Grand-Ridge, through a low part thereof, intersected by deep lakes or lochs: its object is a connection between the East and West Seas, by Linnke Loch and Murray Firth, for large ships drawing near 20 feet of water, and for avoiding the northern voyage by the Orkneys, or through *Pentland Firth*. Inverness is the 63d British town, with a population of 8732 persons. Nairn, Cromarty, and Fort-George are also considerable towns on this line. It commences in the tide-way in Loch *Beauly* at Clachnacarry bason, and, after passing through two large and two small inland lakes, it terminates in the tide-way in Loch *Eil* at Corpach bason. From the sea-lock at Clachnacarry to the 2d lock, about ¼ of a mile, it is level, with high water in Loch *Beauly*, and nearly parallel thereto; thence for one mile to the 6th lock is a rise of 45 feet by 5 locks; thence through Lochs Doughfour and Ness to Fort Augustus is 28 miles, and level; thence to the east end of Loch Oich at the 13th lock, 5½ miles, is a rise of 53 feet by 7 locks; thence through Loch Oich, and the deep-cutting on the grand ridge west of it, is 54 miles and level; at the end of which the lock N° 12, at the east end of Loch Lochy, makes a fall of 19 feet; thence through Loch Lochy to near Tor Castle is 10¼ miles, and level; and thence to the sea-lock at Corpach, 2¾ miles, is a fall of 79 feet by 10 locks: in all 23 locks, besides the sea or entrance locks. This canal is 110 feet wide at top, 50 at bottom, and 20 feet deep; the locks are 152 feet long and 38 feet wide. At Clachnacarry and at Corpach are basons, each 400 yards long and 70 yards wide. Twenty-two miles of this navigation is through a surprising fresh-water lake, called Loch Ness, of ¾ to 1¼ mile in breadth, the middle part being 129 fathoms in depth! and its bottom muddy: this loch and the next never freeze, and it is said that the waters thereof do not corrode iron. Loch Lochy is another large lake, 10½ miles in length, and from ¾ to 1¼ mile in width, and its greatest depth 76 fathoms, through which this navigation passes: it has a secure little harbour, 200 fathoms long and 150 fathoms wide, at its eastern end. Another smaller lake is found on this line, called Loch Oich, 3½ miles long, from 1/16 to ¼ of a mile wide, and 26 fathoms in depth in the deepest part, its bottom being a soft mud. Loch Doughfour, the remaining one of the four, is 1¼ mile long, about ¼ of a mile wide in its widest part, and about 40 feet deep. The number of swing bridges is 23; there are 5 culverts with 1 to 4 arches each, and an aqueduct bridge of 4 ten-feet arches at Ley Bridge: the deep-cutting near Laggan is to be 45½ feet deep on the summit, and is estimated to cost 11,262l. New courses are required to be cut for the river Spean, and at Fort Augustus for the river Ness; the steep hills adjoining, rendering it necessary for the canal to occupy the old bed of the river for some distance in those places. A large weir is to be made at the east end of Loch Doughfour, to hold up its waters to the level of Loch Ness, and several smaller weirs are to be made. Loch Oich is to be deepened 1540 yards in length, at the expence of 11,550l. This canal is most amply supplied with water on the summit, not only for the lockage, but for the working of mills out of the different pounds, which will doubtless hereafter prove of immense advantage to the country. In 1774 Mr. *Watt* was employed to survey this line, who estimated a 12 feet deep canal, in the place of the present one, to cost 164,031l., exclusive of the land. In 1801 Mr. *Thomas Telford* was employed by Government to survey the canal above described, assisted by Mr. *Murdoch Downie*, very full particulars of which will be found in the *Reports*, printed by order of the house of commons 14th June 1803 and 10th of April 1804; in which Mr. *William Jessop*'s estimate, amounting to 474,531l. (exclusive of 23,000l. for land and mooring-chains) is given; and walled locks are recommended, on account of the loss of time in filling the chambers of those unwalled. By the first act above, 20,000l., by the next 75,000l., and by the last 50,000l. of the public money were granted, for carrying on this great work, under the direction of Mr. *Thomas Telford*. In October 1804, seven miles in length next Inverness were digging, and the entrance basons were in hand. In August 1805, the new channel for the river Ness was cutting, the first lock new Inverness was building, 1000 men being employed at this end. It is proposed to place mooring chains on the shores of Lochs Ness and Lochy, on account of their being too deep for good anchorage. On Loch Ness government have had a galley of 37½ tons burthen since 1727, in which period, to 1803, five of them had been worn out: the worm so fatal to wood in some waters is not troublesome here. At Inverness the spring tides rise 11 to 15 feet, and the neap tides 7 feet; at Fort William they rise 12 and 5 feet. Cromarty Bay in Murray Firth, about 18 miles east of the beginning of this canal, was surveyed by Mr. *Thomas Telford* in 1801; the spring tides here rise 14 or 15 feet, and the two piers of this harbour appear to offer a safe retreat for ships, secure from

every wind, and where warehouses are only wanting for the accommodation of a large fleet.

ITCHING RIVER. Acts 16 and 17 of Cha. II., and 7 and 35 of Geo. III.—The general direction of this navigation is nearly north, for about 14 miles, in Hampshire; it is but little elevated above the sea; its objects are the supply of Winchester with coals, deals, &c. and of Southampton with flour and other agricultural products, and the trade between these towns. At Northam it is joined by the *Southampton and Salisbury* canal. Southampton is the 68th British town, with a population of 7913 persons; and Winchester the 103d, with 5826 persons. It commences in the tideway in *Southampton Water* near Southampton, and terminates at Winchester. This navigation is the sole property of *James D'Arcy*, Esq.; and he and his predecessors were the sole carriers, or nearly so, thereon, until 1795, when commissioners were named, in the above act, for fixing rates of tonnage, on payment of which it is in future to be a free navigation. It was intended to widen the channel between Woodmill and the Roman ditch, and to erect pound-locks where necessary.

IVEL RIVER. Act 30 Geo. II.—The direction of this river is nearly south, for about 11 miles, in the county of Bedford; it is not very greatly elevated; its objects are the supply of the towns of Biggleswade, Shefford, and the adjoining country, with coals, deals, &c. and the export of farm produce. It commences in the great *Ouse* river at Temsford, and terminates at the town of Shefford. On the lower end of this navigation, sluices with separate and moveable upright planks instead of gates are in use, as before mentioned. Soon after the passing of the act, the navigation was completed to Biggleswade; but the remainder of the distance to Shefford, 5¼ miles, has not yet been made navigable, for want of money. In the present year (1805) Mr. *Benjamin Bevan* was employed to survey and estimate the expence of this part, which he states at 5900l.; the rise about 26 feet, to be effected by 5 locks; the toll on this distance is to be 1s. 6d. per ton. It is stated that the part of this navigation below Biggleswade has, in the last seven years, produced a net 400l. per annum, towards the reduction of the debt at first incurred. Several years ago the *Biggleswade and Hertford* canal was proposed to join this river at Biggleswade.

IVELCHESTER AND LANGPORT CANAL. Act 35 Geo. III.—The direction of this navigation is nearly east for about 7 miles in the county of Somerset: it is not much elevated: its objects are the import of coals and export of farming products; Langport and Ilchester, or Ivelchester, are considerable towns; it commences in the *Parret* below the town of Langport, and terminates at the town of Ilchester, following the course of the Yeo river part of the way, and the remainder by a canal; the company were authorized to raise 8,000l., the amount of shares being 50l. each: half-mile stones are to be erected on this navigation.

KENNET RIVER. The course of this river is nearly east for about 20 miles in the county of Berks, it has a considerable elevation: its objects are the supply of Newbury, the export of farming products, and forming part of the most direct communication between London and Bath and Bristol; Reading and Newbury are considerable towns. It commences in the *Thames* river about a mile below Reading, and terminates in the *Kennet and Avon* canal a little above Newbury; on this navigation unwalled locks were very early in use; in Feb. 1800 it was proposed to improve this navigation through the borough of Reading. This company has given notice that as carriers, they will not be answerable for the damage goods may sustain by fire or unavoidable accidents. Immense beds of Peat are found near Reading, which is used for considerable distances as a manure.

KENNET AND AVON CANAL. Acts 34, 36, 38, 41, and 45 of Geo. III.—The general direction of this canal is nearly east for 55½ miles in the counties of Somerset, Wilts, and Berks. The middle part is considerably elevated, and crosses both the western and eastern branches of the grand-ridge, the part between these points, crossing the heads of the valleys which fall to the southern coast, while the ends are in those vales falling to the *Bristol Channel* and the *Thames*; its objects are a communication between Bristol, Bath, and London, and the supply of the country west of Hungerford with coals from the mines connected with the *Somersetshire Coal* canal, which joins at Monkton Combe; at Widford it connects with the *Dorset and Somerset* canal, and at Semington with the *Wilts and Berks* canal. Bath is the 12th British town, with 32,200 inhabitants; Devizes is the 69th, with 7,909 persons; Bradford the 78th, with 7,302 persons; and Trowbridge the 104th or 105th, with 5,799 persons; Melksham, Hungerford, and Newbury, are also considerable towns on or near this canal. This canal commences in the *Avon* river at Dole-Mead in Bath, and terminates in the *Kennet* river a little west of Newbury; the branches that were at first proposed to Calne and Chippenham, have been superseded by the *Wilts and Berks* canal, and its branches. From the *Avon* to near Bathampton ¾ of a mile is a rise of 56½ feet; thence to Trowle bridge, 10½ miles is level; thence to Devizes, 9¼ miles, is a rise of 30½ feet; thence for 20 miles along the summit-pound (and through the tunnel of 2¾ miles, at first proposed) to Crofton; thence to Hungerford is six miles, with a fall of 104 feet; and thence to the *Kennet* near Reading, 9 miles, is a fall of 72 feet. By the second act, the company were authorised to raise a part of their summit-pound at its eastern end, so as to pass the summit by a moderate deep-cutting instead of the tunnel above mentioned, and to supply the new summit with water by a large steam-engine. This canal is calculated for 50 ton boats; at Trowbridge there is a bason 129 yards long and 60 wide, and another between Lyncombe and Widcombe. There is a considerable deep-cutting near Burbage: there are two large stone aqueduct bridges over the *Avon* river, one called Dundas, the other is at Avon-cliff. Progress was first made in completing parts of this canal at its eastern end, and in October 1798, the same was opened from Reading to Hungerford; in July 1799 the same was opened to Great Bedwin, near the beginning of the summit: in May 1801, the other end of the line was opened from Bath to Devizes. The company were authorised to raise 810,000l. besides a farther sum by the last act; the original shares were 120l. each, but a great number of defaulters appeared among the subscribers, (no less than 450 shares it was said) and those remaining being called on for 17l. 4s. 7½d. on each, made the amount of these old shares 137l. 4s. 7½d. each, before the act of 41 Geo. III. restrained any further calls on their shares, and created a new set of shares of the amount of 60l. each. The shares of several discontented proprietors were directed to be purchased. This canal passes through Sydney-gardens near Bath, which are laid out and appropriated to pleasurable parties like our Vauxhall gardens. The rates of tonnage are from 1d. to 2½d. per ton per mile on different goods, and others are fixed for the distance between Bath and Devizes, for which see *Phillips's* 4to. *History, Appendix*, pages 142 and 143. Mr. *John Rennie* is the engineer, whose superior skill has been shewn in surmounting the great difficulties that have attended the construction of this canal: between Avon-Cliff and Bradford, a single slip cost, it is said, 1000l. repairing. A canal passing through nearly this tract of country was proposed in 1754. The new shares in 1802

bore a premium, notwithstanding no interest is to be received on them until the line is completed, which was required by the first act to be done in the next year, (1806); we sincerely wish this may be the case. Some years ago it was proposed to extend a branch of the *Basingstoke* canal to join this at Hampstead: in 1796 there was an intention of extending this canal by the side of the *Avon* to Bristol.

KETLEY CANAL. The general direction of this canal, or water-level, is about E.; originally it was about 1¼ mile in length, in the county of Salop; it has a great elevation, being within 7 or 8 miles of the grand ridge on its western side; its objects are the conveyance of coals, iron-ore, and lime-stone, the export of heavy iron goods, &c.; it was contrived by Mr. *William Reynolds*, and cut in 1788 at the sole expence of Messrs. *William Reynolds and Co.* and in the year 1793, 1 mile and 188 yards of this level at its east end were sold to the *Shrewsbury* company, and made part of their canal; the price was 840l. half the original cost, with the condition that Messrs. *Reynolds and Co.* should pay 2d. per ton per mile for their goods passing on the *Shrewsbury* canal. This canal now, therefore, consists of about three furlongs of level connecting with the *Shrewsbury* canal, at the head of the Wom bridge inclined-plane, and having at its other extremity an inclined plane of 73 feet perpendicular fall to the Ketley iron-works; this inclined plane was the first that was brought into practice in England for the passage of boats, and in 1789 a copper medal or half-penny was struck to commemorate the same. The boats used hereon are 20 feet long, 6⅓ feet wide, and 3 feet 10 inches deep, carrying 8 tons; they are floated into a shallow lock at the top of the plane in order to place them upon the wheeled carriage or cradle, which carries them down the plane, after the water in the lock is drawn off into a side-pond, to be pumped up again by a steam-engine into the upper pound, and by which no water is lost out of the upper pound or water level. The inclined plane is double, and a descending loaded boat draws up an empty one or but about one-third laden, by means of strong ropes winding round a barrel at the head of the plane, the velocity being regulated by a brake-wheel; of this plane we have before spoken. Several of these small boats linked together are towed along the level by one horse, and to guide them round the projecting turns of the bank, slide-rails are placed thereon.

Keyingham-Level. In the year 1802, Mr. *William Chapman* made a survey for a navigation, and drainage-cuts, from the *Humber* river at Stone-creek, to Roofs-bridge and Owstwick-carr gate, in the East-Riding of Yorkshire, the estimated expence thereof being 1500l.; the canal was proposed to pass near the town of Keyingham, its objects being the import of coals, &c. and the export of agricultural articles.

KIDWELLY CANAL. The length of this canal is about 3¼ miles, in Caermarthenshire, in South Wales, it is the private property of Mr. *Keymer;* it extends from the tide-way at the town of Kidwelly to Mancha coal and lime-works, belonging to Mr. Keymer, through whose estate the canal is also cut: its object is the export of lime and coals.

LAGAN NAVIGATION, (*Ireland*). This is one of the navigations which the Irish parliament have assisted with sums of money, with the view of facilitating the working of the collieries with which it connects; for this navigation and its collieries, various sums of public money were advanced between 1753 and 1770, amounting to 40,304l.

LANCASTER CANAL. Acts 32, 33, 36 and 40 of Geo. III.—The general direction of this canal is nearly S. for 75¾ miles, in the counties of Westmoreland and Lancaster; the greater part of its northern end skirts along near the sea-coast, but the southern end is considerably elevated, crossing within two miles of its termination the Haslingden and Liverpool branch from the grand-ridge. Its objects are, the interchange of the lime-stone of the northern parts, for the coals and cannel of the southern parts of the line, the supply of Lancaster and Preston, &c.: it is to connect with the sea at Glasson Dock by a cut of 4 miles from Galgate on the line of the canal; it crosses the *Loyne* and *Ribble* rivers, but without connecting with them, and it likewise passes under the *Leeds and Liverpool* canal. Preston is the 37th British town with 11,887 inhabitants, Wigan is the 42d, with 10,989 persons, Lancaster the 56th, with 9,030 persons, and Kendal is the 88th, with 6,892 persons; Burton, Garstang, Kirkham, and Chorley are also considerable towns on this line. This canal commences in a bason at Kirkby-Kendal, and terminates in another at West Houghton: to Wharton-Craggs lime-works there is to be a cut of 2½ miles, and another of 2⅞ miles to Duxbury near Chorley. From the bason at Kendal to Greenhead farm (through the Hincaster or Leven tunnel) is 5⅛ miles and level; thence to near Borwick, (near the Wharton branch) 9¾ miles, is a fall of 65 feet; thence to the south side of the meadows south of Preston is 42⅛ miles and level! thence to Clayton Green 3⅛ miles is a rise of 222 feet, and thence to West Houghton 15⅝ miles is level; the Wharton and Duxbury cuts are level. This canal is 7 feet deep, the boats are 56 feet long and 14 feet wide, carrying 60 tons; and the Glasson branch has a fall of about 52 feet. There are two tunnels, one at Hincaster near Leven's Park of about 800 yards long, and another through the Whittle Hills near Chorley, which proved a most difficult one to execute; at Ashton near Lancaster there is an amazing piece of deep-cutting. At Lancaster there is a most surprising aqueduct bridge 51 feet high, over the *Loyne* river, consisting of 5 arches of 70 feet span each. (See our article BRIDGE.) There are other aqueducts over the *Ribble* at Preston, the Wyre at Garstang, the Beeloo near Bethorn, &c.; and it is passed on an aqueduct 60 feet high near Bark-mill not far from Wigan by the *Leeds and Liverpool* canal. At Kendal the canal is supplied with water by a feeder of 1 mile in length from the river Mint: water from all mines within 200 yards may be taken. The part of the line between Wheelton (near to Clayton Green) and the south end of the long level is at present supplied with a rail way, but we believe only as a temporary measure. Mr. *James Brindley* was employed in 1772 to survey a part of this line, the whole of it was soon after surveyed by Mr. *Robert Whitworth*, and in 1791, Mr. *John Rennie* was employed, who has had the direction of the works upon it, which will redound to his lasting credit. The company is authorised to raise 414,000l. in 100l. shares, and 200,000l. more in shares of 30l. each. In July 1796, the last arch of the Lancaster aqueduct was completed: in September 1805, it was stated that the shares divided 1l. per cent. From Bolton to Lancaster and thence to Preston it was opened in November 1797, and in a few years after the whole of the long level was completed. In June 1803, the Whittle tunnel was completed, and 1½ mile of the rail-way, so that coals passed from West Houghton to Bramber-bridge, and in 1805, the remainder of the railway was opened for conveying coals to Preston, Lancaster, &c. At Hest this canal passes along close to the sea beach. The rates of tonnage are, for coals 1½d. per ton per mile; for lime-stone, slate, salt, bricks, stone, iron-ore, gravel, sand, clay, and manures ½d. per ton per mile; for lime and iron 1d. per ton per mile, and for timber, wares, and merchandize, 2d. per ton per mile. Coals are not to pass the intended locks N. of Chorley under 2s. 3d. per ton, which is to pass them for 18 miles N. of Chorley. It is provided in

the *Ulverston* canal act (33 Geo. III.) that coals from this canal may cross the bay of Morecambe to that place without being subject to the sea duty.

LARK RIVER. This river (sometimes called the Mildenhall) has its course nearly S. E. for about 22 miles in the county of Suffolk, after skirting the bounds of Cambridge for some miles. Bury St. Edmunds is the 71st British town, with a population of 7,655 persons; Mildenhall is also a considerable town on the line of this navigation, which commences in the great *Ouse* river at Prick-willow, (about 4½ miles below Ely) and terminates at Bury St. Edmunds. Its objects are the import of coals, deals, &c. and the export of farming products. The lower part of its course is embanked on both sides through the fens. It is generally very short of water in the autumn. In 1789, this river was proposed to be crossed by the *Bishopstortford and Wilton* intended canal; and in 1802 it was proposed to be joined at Bury St. Edmunds by the *Stowmarket and Bury* rail-way.

LEA RIVER. Acts 12 Geo. II. and 7, 19, and 45 of Geo. III.—The general direction of this river is almost north for about 28 miles, between the counties of Middlesex and Essex and in Hertfordshire; it is not much elevated. Its objects are the supply of Hertford and all the surrounding country with coals, deals, &c. and the export of farming products, of which malt from Ware forms a considerable part. At Bromley near Bow it connects with the *Limehouse* canal, and near Hoddesdon it is joined by the *Stort* river. Hertford, Ware, Hoddesdon, Waltham-Abbey, Enfield, and Stratford are considerable towns on or near this navigation. It commences in the *Thames* river at Bow-Creek near the *East-India Docks*, and terminates in the town of Hertford: it has a short cut to the town of Waltham-Abbey. This river, which seems subject to floods, was originally made navigable in some places by weirs and flush-sluices, or turnpikes. In 1767, Mr. *John Smeaton* calculated one of those sluices to let down 1429½ cubic feet of water per minute on an average, a consumption which greatly injured the mills; the early pound-locks erected on this river were without walled chambers. In 1771 some of the turnpikes were removed and locks built; in 1781, Mr. *Smeaton* was again called in to give an opinion on the very leaky state of the locks. In 1772, and again in 1802, this river was proposed to be joined at Waltham-Abbey by the *London and Waltham-Abbey*, with another junction therewith at Lee-bridge; and in 1792, it was proposed to be joined at Hertford by the *Leicester and London* canal. Several years ago the *Biggleswade and Hertford* canal was proposed to join this river at Hertford. Between Hertford and Ware, the *New River* or aqueduct for the supply of London, has its rise, partly out of the chalk hills, and partly by a feeder out of this river, and pursues its devious course for near 40 miles. This great work was begun by Sir *Hugh Middleton* in 1608; in 1773, Mr. *James Sharp* suggested the making of the New River navigable, and continuing it by a level cut to the *Thames* near Reading. In 1803, Mr. *John Rennie* was employed by government to survey the lower part of the course of the *Lea* river, and to construct embankments across, for filling this extensive vale with water in case of an invasion: the gates intended to produce these effects, are vessels that can on the shortest notice be floated to and sunk in their proper places, to stop the water, as before described.

Leatherhead and Thames Rail-way. In 1801, it was proposed to make a rail-way from a bason to be made on the banks of the *Thames*, in West Moulsey (opposite Sunbury) to the town of Leatherhead in Surry, through the parishes of Walston, Cobham, Stoke-Dawbernon, Little Bookham, Great Bookham and Fetcham.

LEE RIVER, (*Ireland.*) For improving the navigation of this river, the Irish parliament between 1753 and 1770, granted 2,000l. of the public money.

LEEDS AND LIVERPOOL CANAL. Acts 10, 23, 30, and 31 of Geo. III. The general direction of this canal is between N. E. and E. by a very crooked course of 130 miles in the counties of Lancaster and York; it crosses the grand-ridge by a tunnel, near Colne, and at Red-Moss and Aspule crosses the Haslingden and Liverpool branch of the grand-ridge. Its objects are a communication between the ports of Liverpool and Hull, the export of the immense stores of coals, cannel, and lime-stone, that are found on parts of its course, and the supply of the great towns thereon with the agricultural products of the intermediate country. At Brier' mill it connects with the *Douglas* navigation (now belonging to this company, by a purchase under 23 Geo. III.); near Bark-mill not far from Wigan it crosses the *Lancaster* canal (but is 60 feet above it on an aqueduct-bridge.) At Church it connects with the *Haslingden* canal, at Skipton with *Thanet*'s canal, and at Windhill with the *Bradford* canal. Liverpool is the 4th British town with 77,653 inhabitants; Leeds is the 8th, with 53,162 persons; Blackburn is the 36th, with 11,980 persons; Wigan is the 42d, with 10,989; Bradford is the 95th, with 6,393 persons, and Hunslet the 104th or 105th, with 5,799 persons: Ormskirk, Chorley, Burnley, Colne, and Skipton are also considerable towns on or near this line; which commences in the town of Liverpool (on the bank of the *Mersey*, but does not connect therewith) and terminates in the *Ayre and Calder* navigation in the town of Leeds; there is a cut to Ighton-hill collieries, another to Mr. Walton's Altham collieries; and provision is made for cuts to be made by the earl of Balcarras and Mr. Shuttleworth between their coal works and the line. The old bason at Liverpool is 52 feet above low-water mark in the *Mersey* river, from thence to Newborough, 28 miles, is level; thence to the beginning of the deviation that was last made in the line, near to the town of Wigan, 7 miles, is a rise of 30 feet, by 5 locks, (this last length being sometimes called the *Upper Douglas* navigation, of which it formerly was a part), thence to Bradshaw-hill near Aspule 3 miles, has a rise of 279 feet, by 28 locks, (the *Lancaster* canal being crossed in this distance) thence to the aqueduct over the Derwent near Blackburn, 19¼ miles, is level; thence to Grimshaw near Blackburn, ¾ of a mile, has a rise of 54¼ feet, by 7 locks; thence to the end of the deviation at Barrowford near Colne is 24 miles and level; and thence to the beginning of the summit pound near Colne is ¾ of a mile with a rise of 67¾ feet, by 7 locks. The summit-pound, passing through the Foulridge tunnel, extends to near Thornton, about 6¼ miles and level; thence to Holme-bridge near Gargrave is about 7½ miles, with about 150 feet fall, by 15 locks; thence to Gawthorpe-hall near Bingley is 17 miles and level; thence to the junction of the *Bradford* canal is about 4 miles and 100 feet fall by 11 locks; and thence to the *Ayre and Calder* navigation at Leeds is about 12½ miles, and 160 feet fall, by 18 locks: the whole lockage being 840½ feet by 91 locks, which are each 70 feet in length, and 15½ feet in width; the breadth of the canal at top is 42 feet, and it is 4½ feet deep in water. The boats are keel-bottomed, and carry 30 tons of goods, with which they can go down the *Ayre* and *Ouse* as far as Selby; between Leeds and Wigan, 100 flatts of 42 tons burthen are employed in the coal and cannel trade, passage-boats also ply regularly on this part. At Leeds there is a fine bason, and there are spacious warehouses belonging to this company at the north-east corner of Liverpool town, and it was intended in 1801, to construct a new bason from the North Graving-Dock on this canal, to the top of Plumbe-street, for which

7000 cubic yards of earth were to be excavated, and the whole to be lined by 1200 cubic yards of stone masonry. The coals are thrown out of the boats on a branch that proceeds near to the *Mersey*, and slide down a steep bank to a yard by the water side. At Foulridge there is a tunnel of 1030 yards in length, and 23 yards below the highest point of the hill; the soil of which proved so very loose, that only 700 yards could be worked under-ground, the remainder was obliged to be opened from above, from 10 to 20 yards deep, and 20 to 30 yards wide at the top, although it was supported with immense labour and expence by timbers to prevent its falling, until the tunnel arch was formed, which is 18 feet high and 17 feet wide withinside; it is arched with stone. At Furnloy near Burnley, there is another tunnel. At Cottingley below Bingley, and near Gargrave there are considerable aqueduct bridges over the Ayre river, and several lesser ones in different places. Mr. *Longbottom* made a survey for this canal in 1767, which was revised by Mr. *James Brindley* in 1768, under whom the canal was begun, after which Mr. *Robert Whitworth* and Mr. *Fletcher* were employed thereon. In 1770, the eastern end of the line was completed from Leeds to Holme-bridge, a distance of 33½ miles; about the end of 1794 this was extended to near Foulridge. May 1, 1796, the Foulridge tunnel was completed and the line opened to Burnley. In May 1801, the Furnloy tunnel was finished, and the navigation extended to Enfield within 4½ miles of Blackburn; and in July 1801, the Altham branch was opened. The western end of the line was begun as early as the other, and in 1770 the same was opened from Liverpool to the *Douglas* old navigation at Newborough, 28 miles; and on 19th October 1774, the present navigation was completed to Wigan. This company was authorized to raise 600,000l. the amount of shares 100l. The rates of tonnage are, on lime-stone and other stones ½d. per ton per mile, on coals and lime 1d. and on all other articles 1½d. per ton per mile. No wharfage to be taken unless goods remain 6 hours. In September 1805, the company proposed lowering their rates of tonnage on the *Douglas* lower navigation. About the year 1794, a branch of the *Manchester Bolton and Bury* was proposed to join this canal at Red-Moss near Wigan. In September 1802, it was proposed to make a branch from this canal near Wigan to *Bridgewater's* canal at Pennington; also a branch or rail way from it to Low-hall collieries.

Leicester Navigation. Acts 31, 34, (for *Ashby* Canal) and 37 of Geo. III.—The general direction of the line of this navigation is about south, following nearly the course of the Soar river, for 14 miles in the county of Leicester, its Charnwood Forest branch is considerably elevated. Its objects are the supply of Leicester with coals, deals, and general merchandize, the export of coals and limestone from the mines on its branches, and the farming products of the country. On the completion of the *Leicester Union* canal it will become a considerable thoroughfare. At Turn-water Meadow in Cossington, it is joined by the *Leicester and Melton-Mowbray* navigation. Leicester is the 22d British town with a population of 16,953 persons; Loughbourough and Mount-Sorrel are also considerable towns on the line. It commences in the bason of the *Loughborough* navigation at that town, and terminates in the *Leicestershire and Northamptonshire Union* canal, at Leicester. From the bason at Loughborough, a *rail-way* branch of 2¼ miles, and a rise of 185 feet, extends westward to a bason at Forest-lane, at the east end of the Charnwood Forest *water-level*, which level extends 8¼ miles to near Barrow-hill, having a side cut of ½ of a mile to Thringston-bridge, and level. From the west end of the water-level a rail-way extends ⅞ of a mile further to Clouds-hill lime-works, and there connects or very nearly so with a branch of the *Ashby-de-la-Zouch* canal; there is a short rail-way branch of six chains to Barrow-hill lime-works; the Thringstone-bridge branch is also continued by a rail-way to Coal-Orton in two branches of 1½ mile, and another of ¼ of a mile to Swannington-common coal-works. From *Loughborough* bason to the junction of the *Leicester and Melton-Mowbray* navigation it is 3 miles, and level, and thence to the *Leicestershire and Northamptonshire Union* the distance is 11 miles, with a rise of 45 feet. On Charnwood Forest there is a reservoir for supplying the water-level, and a feeder of ¾ of a mile in length to convey the water to it. Near the west bridge in Leicester there is a bason for the use of this navigation. Mr. *William Jessop* was the engineer; in December 1793 the part of the line between Loughborough and Sielby, near Mount Sorrel, was opened, and in February 1794 the remainder of the same to Leicester was opened. The company was authorised to raise 84,000l. The rates of tonnage are various: see *Phillips's* 4to. *History*, *Appendix*, p. 12. On the making of the *Ashby* canal, with branches to the neighbourhood of the collieries connected with the Charnwood level, the company were allowed 2s. 6d. per ton on all coals dug in Swannington, Coal-Orton, or Thringstone parishes, and carried through Blackfordby, on the *Ashby* canal. The company are authorised to make rail-ways to any mines within 2000 yards of the water-level; and are to guarantee the *Loughborough* company a receipt of 2000l. per annum, on condition of their taking 1s. 6d. or less per ton (but not less than 10d.) for coals passing from Loughborough to the *Trent* river.

Leicester and London Canal. About the year 1792 printed proposals and a plan were circulated, for a canal from the *Leicester* navigation at that town to the *Lea* river at Hertford, a distance of 77 miles; passing Market-Harborough, crossing the *Nen* river near Wellingborough, and connecting with the *Ouse* navigation at Bedford; its professed object, as a rival to the *Grand Junction*, was the forming of the shortest communication between London, Liverpool, Hull, and Lynn, and the intermediate large trading towns, mines, &c.

Leicester and Melton-Mowbray Navigation. Acts 31 and 40 Geo. III.—The general direction of this navigation is nearly E. following the courses of the Wreak and Eye rivers, for about 12 miles, in the county of Leicester; it is not greatly elevated in any part, its objects are the supply of Melton-Mowbray with coals, deals, &c. and the export of the farming products of the country; it commences in the *Leicester* navigation at Turn-water Meadow in Cossington, and terminates in the *Oakham* canal, at the town of Melton-Mowbray. The company were authorised to raise 40,000l. The original rates of tonnage may be seen in *Phillips's* 4*to*. *History*, *Appendix*, p. 13, but these were altered and increased by the late act above, and several regulations made respecting tolls with the *Oakham* company. This navigation was completed in a few years after the passing of the first act.

Leicestershire and Northamptonshire Union Canal. Acts 33 and 45 Geo. III.—The general direction of this canal is nearly S.E. by a crooked course of 43¾ miles in the counties of Leicester and Northampton; its middle part is considerably elevated, and skirts along the eastern side and near to the grand-ridge for several miles: its objects are the formation of a junction between London, Hull, and Lynn; the supply of the country through which it passes with coals, deals, &c. and the export of farming products; it is to connect at Northampton with a *rail-way* branch of the *Grand Junction*. Leicester is the 22d British town, with a population of 16,953 persons, and Northampton is the 85th, with 7,020 persons, Market-Harborough

is alſo a conſiderable place near the line. This canal commences in the *Leiceſter* navigation in the town of Leiceſter, and terminates in the *Nen* river at the town of Northampton; there is a cut of 3¾ miles in length to Market-Harborough. From the *Leiceſter* navigation to Fleckney near the Saddington tunnel is 12¾ miles, with 160 feet riſe; thence to near Great Oxenden 13¼ miles are level; thence in ¼ of a mile is 50 feet riſe; thence the ſummit-pound extends through Oxenden and Kelmarſh tunnels to near Maidwell, 4⅞ miles and level; thence to the junction of the North river near Northampton are 11¼ miles, with a fall of 197½ feet, and thence to the head of the *Nen* navigation is ¾ of a mile and level. The Market-Harborough cut is level. At Gumley there are a baſon and warehouſes. There are four tunnels on this line, viz. at Foxton, of 1056 yards in length; at Kelmarſh, of 990 yards in length; at Saddington, of 880 yards in length, and at Oxenden, of 286 yards in length. On Oxenden and Kelmarſh brooks are the aqueducts for the ſupply over the ſummit-level, but flood-waters alone are to be taken. There are a great number of ſmall aqueducts over the ſtreams which it paſſes. Mr. *John Varley*, ſen. and Mr. *C. Stanley*, jun. are the engineers. In March 1800, the tunnel at Saddington was finiſhed, and the line opened from Leiceſter to Gumley, a diſtance of 17 miles; but ſmall progreſs appears to have been ſince made with the other three tunnels, and the remainder of the line, intended to form the union. The rates of tonnage on coals and coak are 2½d. per ton, per mile, but not to exceed 3s. for any diſtance; for lime, lime-ſtone, dung, and manure 1½d. per ton, per mile, but not exceeding 2s. 6d. per ton, on any diſtance; for live cattle, ſtones, bricks, tiles, ſlates, ſand, iron-ſtone, pig-iron, and pig-lead, 2d. per ton, per mile, and for other goods 3d. per ton, per mile; troops and government ſtores are exempted. Road-materials, and manures (except lime) for the uſe of the proprietors of lands on the pounds, may alſo paſs the locks when the water runs waſte thereat. The towing path may be uſed as a bridle and drift-way by the owners of adjoining lands. By the firſt act the company were authorized to raiſe 300,000l. ſhares 100l. each; the laſt act was for varying ſome parts of the line and amending the former one. About the year 1793, the *Uppingham* canal was in contemplation, and its junction with this canal is provided for in the firſt act above. In 1803 it was propoſed to alter and ſhorten the branch to Market-Harborough, and to make a feeder from Willow brook; and in the ſame year Mr. *Thomas Telford* ſurveyed the line of country between Gumley baſon and Buckby wharf on the *Grand Junction* canal, propoſed as a ſubſtitute for the ſouthern part of the line to Northampton.

Leominster Canal. Acts 31 and 36 Geo. III.—The general direction of this canal is nearly W. by a crooked courſe of 45¼ miles, in the counties of Worceſter, Salop, and Hereford; its weſtern end is very conſiderably elevated; its objects are the ſupply of Leominſter and the country with coals from the Pinſax mines near its eaſtern end, and the export of iron, lime, and agricultural products: Kington, Preſteign, Leominſter, Ludlow, Tenbury, Cleobury-Mortimer, and Bewdley are conſiderable towns on or near to the line of this canal: it commences in the *Severn* river at Areley near Stour-port, and terminates at the town of Kington: it has two ſhort cuts to mills near Tenbury. From the *Severn* river to the eaſt end of the Pinſax tunnel it is 3 miles, with a riſe of 207 feet; thence through that tunnel, and the Souſnant tunnel to its weſtern end, it is 9 miles and level; thence to the river Rea aqueduct is 1 mile, with a fall of 30 feet; thence to Letwich brook, 7 miles, it is level; thence to Wilton, 4½ miles, is a riſe of 36 feet; thence to near Luſton, 5¼ miles, is level; thence to Leominſter, 1½ mile, is a fall of 18 feet; thence to near Kingſland are 4½ miles, with 64 feet riſe; thence to Milton are 3½ miles, with 37 feet riſe; thence to Stanton-park are 2½ miles, with a riſe of 152 feet, and thence to Kington are 4 miles, and level. At Pinſax is a tunnel of 3850 yards, and the other at Souſnant is 1250 yards in length. There are conſiderable aqueduct-bridges over the Rea river at Knighton, over the Teme at Woferton, and over the Lugg at Kingſland: a power is provided in the act for inclined-planes inſtead of locks, if the ſame ſhould be found moſt eligible; ſprings of water within 2000 yards of the line may be taken. Mr. *Thomas Dadford*, jun. is the engineer. In July 1796 the difficult tunnel at Putnal-field in Souſnant was finiſhed, and in November 1796, near 20 miles of canal, from Mamble coal-works to the town of Leominſter were opened, and coals, which before ſold there at 1s. 6d. per cwt. were at once reduced to 9d. per cwt.! On the 1ſt of June 1797, the entrance of the canal from the *Severn* was opened: ſince which conſiderable progreſs has been made in the works: in May laſt (1805.) the Pinſax mining company was propoſed, for opening new coal and iron mines near that place, on the line of the canal, which was expected to facilitate its completion. The *Leominſter* company have been authoriſed to raiſe 370,000l. The tonnage rates are too long for our room, they will be found in *Phillips's* 4to. *Hiſtory*, *Appendix*, p. 5 and 6. About the year 1794, the *Welſhpool and Leominſter* canal was propoſed to join this at Woferton.

Liffey River, (*Ireland*). The direction of this river is nearly weſt, in Dublin county, from the bay of Dublin to the entrance baſon of the *Grand Canal* in Dublin city, where alſo are a Harbour and Docks that have been improved, under Mr. *William Jeſſop*; the ſpring tides riſe only 13 feet at theſe dock-gates. In the year 1800 it was propoſed to avoid the bar at the mouth of the *Liffey*, by cutting a new channel or canal for ſhips from Dunleary to Kingſtead dock; it was alſo propoſed to make Dalkey ſound a ſafe harbour, and to make a cut from thence to the *Grand Canal* baſon; the bill for this purpoſe was paſſed by the commons, but was rejected by the houſe of lords. Ormond bridge, on this river, was carried away by a flood, and in September laſt (1805,) the corporation of Dublin harbour offered premiums for the beſt plans for a new bridge at this place.

Limehouse Canal. The direction of this canal is about N.E. for 1½ mile, in the county of Middleſex; it is but little elevated above the level of the ſea; its object is to ſhorten the navigation between the *Lea* river and the port of London, by avoiding the circuit round the Iſle of Dogs; it commences in the river *Thames* near Limehouſe church, and terminates in the *Lea* river at Bromley near Bow, having a riſe of 17½ feet. This canal was cut at the expence of the *city of London*, in an early part of the preſent reign, and its locks, which are of wood, and its other works, form a great contraſt to the improved locks and appendages of modern canals. In 1773 a cut from the intended *London and Waltham-Abbey* canal was intended to join this near Limehouſe church.

Limerick Canal, (*Ireland*). This canal was cut near 40 years ago from the town of Leitrim to a moraſs within a ſhort diſtance, for the purpoſe of bringing turfs, to ſupply the town of Limerick with fuel, and which by their cheapneſs ſuperſeded in a great meaſure the uſe of coals, which coming by a long coaſt-ways navigation were very dear.

Liſkeard Canal. In 1777, Mr. *Edmund Leach* propoſed a canal, or rather a ſyſtem of water-levels and inclined-planes, from the tide-way in the *Looe* river, at Sand-place in Morval to Bark-mill-bridge, in St. Clear; this was propoſed to be accompliſhed by two levels of 9 and 6 miles in

length, (one of which, in its ſerpentine courſe, went within ½ a mile of Liſkeard town,) connected with each other and the river below by two inclined planes for boats, the principles of which have been already explained; the eſtimate was 17,500l. The objects of this navigation were the carrying up of lime and ſea-ſand for manure, and exporting corn, &c.

Liverpool and Runcorn. About the year 1771, a ſurvey was made by Mr. *James Brindley*, for a canal from the town of Liverpool upon one level, to croſs the *Merſey* at Runcorn-gap, by an aqueduct bridge, and join the duke of *Bridgewater*'s canal; beſides the great width of the Merſey at this place, a tide, which riſes 14 feet, was alſo to be encountered.

Llandovery and Llanelly. In September 1801, notices were given for an intended canal from Spitty in the pariſh of Llanelly, on the *Burry* river, through Llangenneech, Llanedy, Landebye, Llandingar, &c. to Llandovery or Llanyneddyvi, in the county of Caermarthen in South Wales. The objects of this canal were ſince accompliſhed by the *Caermarthenſhire* rail-way, over nearly the ſame tract of country.

London Canal. In July 1802, a ſurvey was made for a canal, about in a weſt direction, for near 7 miles, in the county of Middleſex: commencing in the *London Docks*, (and thereby communicating with the *Thames* river,) to paſs Weſt's-gardens, the mount in White-chapel road, and Bethnal-green New road, acroſs Hackney road, through Middleſex-place acroſs Kingſland road, near Iron-monger's alms-houſes, to paſs north of Lady Lumley's alms-houſes at Hoxton, acroſs the city road below the turnpike-gate, acroſs Goſwell-ſtreet, ſouth of Goſwell-place, acroſs St. John's-ſtreet, north of Taylor's brewhouſe, under the field ſouth of the New-river head, over the valley at Bagnige-wells, acroſs Gray's Inn-lane at the weſt corner of the Welſh Charity-ſchool, acroſs the New road to the eaſt corner of Bedford nurſery, acroſs Tottenham court road between St. James's burying-ground and the New-river reſervoir, paſt the fronts of the Artichoke and Queen's-head public houſes, and acroſs the Edgeware road to the baſon of the *Grand Junction* canal at Paddington, the riſe in this diſtance being about 90 feet. The great number of bridges required, the paſſing of the field near Iſlington full of water-pipes in all directions, belonging to the New-river company, by an arch under the ſame, and a large embankment or aqueduct bridge near Bagnige-wells, were difficulties in the way of this project, but to which the ſubſcription for ſhares (which almoſt immediately filled to the amount of 400,000l.) would have been equal; had not the inability of the *Grand Junction* company to furniſh the water neceſſary for the lockage, and the oppoſition of ſeveral powerful land owners, on account of its making ſome alterations neceſſary in their building projects, fruſtrated the ſcheme altogether for the preſent. The weſtern branch of the *Grand Junction*, of which we have before ſpoken, was in contemplation at the time this canal was intended, and water was propoſed to be obtained thereby from the *Thames* for this canal, the Colne millers having it unfortunately in their power, to prevent any being obtained from that river; Mr. *John Rennie*, who gauged the ſtream of the *Thames*, in the dry ſummer of 1794, at Laleham (which is after it has received the main ſtreams of the Colne), found 1155 cubic feet of water to paſs in one ſecond of time, which is 184 times what would be required to be taken from this river higher up near Great Marlow, and brought by the *Grand Junction* level branches, for ſupplying the lockage of this canal, ſuppoſing 60 locks containing 1055 cubic feet each, to be uſed daily. After the oppoſing intereſts were found too ſtrong to leave any proſpects of carrying this canal, a faint effort was made to accompliſh a *rail-way*, through nearly the ſame line, but with no better ſucceſs. In 1773, Mr. *Robert Whitworth* made a ſurvey for the city of London, and recommended a line of canal from the *Lea* river at Lee-bridge, to near the ſame ſpot which the *Grand Junction* baſon now occupies at Paddington: it was intended as branches eaſt and weſt of the *London and Waltham-Abbey* canal.

London Lynn and Norwich. In the year 1785, Mr. *John Philips* publiſhed a thin 4to. treatiſe, to endeavour to call the public attention to a canal between the *Ouſe* river at the port of Lynn, and the *Thames* river at Limehouſe in London, with a branch to the *Yare* river at Norwich. It appears that Mr. *P.* travelled through the propoſed tract of country in 1779 and 1780, but took no levels or other neceſſary particulars, yet ventures to ſtate, that he could execute this canal, 36 feet wide, and 4½ feet deep, for 200,000l. And it is held out, that 28,000 oak Trees, to be planted on the banks of this canal, will, in 50 years, repay all its expences within 60,000l. In 1802 we are told that Mr. *Ralph Dodd* made an effort to revive this or a ſimilar ſcheme, and wiſhed to denominate it the North London Canal.

London and Waltham-Abbey. In the year 1773, at the inſtance of Mr. *James Sharp*, Mr. *Robert Whitworth* was employed by the city of London to ſurvey the line for a canal between the centre of the quarters in Moorfields, London, to the river *Lea* at Waltham-Abbey; a diſtance of 14 miles, almoſt in a north direction in the counties of Middleſex and Hertford; this line was to be level (and about 30 feet above ſpring-tides in the *Thames*,) there was a cut of ½ of a mile, and 33 feet fall propoſed to the *Lea* river at Lee bridge, and another of 4⅝ miles to Wellin's Farm near Paddington, with 49¾ feet riſe; nearly to the ſame level as the *Grand Junction* baſon now has; alſo another cut of near 2 miles to the *Limehouſe* canal near the church, with a fall of 42 feet (to the common neap tides in the *Thames*). The width was to be 60 feet, and depth 4½ feet; in Moorfields and near Holywell Mount, large baſons were intended; between Stamford-hill and High-croſs a very large embankment was neceſſary, another at Hackney brook, and another at St. Pancras brook; at Ponder's end was to be a deep-cutting to avoid the houſes; 15 turnpike road-bridges, and 22 road-bridges of leſſer ſize were neceſſary, the whole expence Mr. *Whitworth* eſtimated to be 98,229l. In 1802, this or a ſimilar ſcheme ſeems to have been in contemplation, but to join the *Thames* near Bell-wharf in Shadwell inſtead of the *Limehouſe* cut.

Looe River. The general direction of this navigation is nearly N. for about 3¼ miles, on the ſouth coaſt of Cornwall, it commences at the ſea near Eaſt Looe, (which is a conſiderable town,) and terminates at Morval bridge, near which, at Sand-place, it was, in 1777, propoſed to be joined by the *Liſkeard* canal; its objects are the carrying up of coals, and ſea-ſand as manure, and the export of agricultural products.

Loughborough Navigation. Act 16 Geo. III.—The general direction of this navigation is nearly S. for about 9 miles, following the courſe of the Soar river, except in the laſt mile, which is a new cut; it is but little elevated; at the baſon, 300 yards from its ſouth end, it is joined by the line of the *Leiceſter* navigation and by the Charnwood-Foreſt rail-way branch belonging thereto. It commences in the *Trent* river (nearly oppoſite to the *Erewaſh* canal, and near to the *Trent* canal) near Sawley, and terminates at the Ruſhes near the town of Loughborough, which is a

considerable place; its objects are as various as the trade of the *Trent*, and the wants of Leicester and other great towns; it forms also part of the line of communication which the *Leicestershire and Northamptonshire Union* canal is to open. On the making of the *Leicester* navigation, that company guaranteed the amount of the tolls on this, to amount to 3000l. annually, on condition of no more than 1s. 6d. per ton on coals or less than 10d. being taken by this company.

LOUTH NAVIGATION. The general direction of this navigation is nearly S.W. for 14 miles in the county of Lincoln, it is but little elevated above the sea; its objects are the supply of Louth, and the adjacent country with coals, deals, &c. and the export of farming produce; it commences at the sea-lock and ebb-gates in Titney Haven (at the mouth of the *Humber* river), and terminates at the town of Louth. From Titney Haven to the Louth river near North Cockerington $9\frac{3}{4}$ miles is level, and but little higher than low-water mark, being a new cut through a low fenny country; thence to Kiddington old mill, $2\frac{3}{4}$ miles, is 24 feet rise; thence to the Leather-mill meadow, $\frac{3}{4}$ of a mile, is $11\frac{1}{2}$ feet rise; thence to Louth is $\frac{3}{4}$ of a mile with 21 feet rise. Mr. *John Grundy* made a survey of this line, which was revised by Mr. *John Smeaton*, in 1760, the estimate of expence being near 15,600l. See *Smeaton*'s *Reports*, vol. i. p. 25.

LOYNE RIVER. The general direction of this river (sometimes called the Lune) is nearly N.E. for about 7 miles in the county of Lancaster; the tide flows through its whole length; its object is the foreign trade of Lancaster, particularly in cabinet-maker's wares, a branch of the *Lancaster* canal is to connect with it at Glasson, where a spacious wet-dock is intended. Lancaster is the 56th British town with 9,030 inhabitants; this river commences in the Irish sea at Sunderland point, and terminates at Lancaster old bridge, some distance below Mr. *Rennie*'s famous aqueduct bridge over this river. It appears, that in the year 1799, 52 vessels cleared out of this river for the West Indies with 11,669 tons of goods in more than 90,000 packages, worth $2\frac{1}{2}$ millions sterling. In October 1799, it was in contemplation, to construct a spacious dock at Thornbush for large ships, with a canal from thence of 6 miles in length through Glasson-dock, and nearly up to the town of Lancaster, to be wide and deep enough for the largest vessels that trade to that place.

LYNN RIVER. The general direction of this river (sometimes called the Lenne, the Nar, or the Setchy) is nearly S.E. by a crooked course of about 15 miles in the county of Norfolk; it is not greatly elevated in any part; its objects are the import of coals, deals, &c. and the export of farming produce; Lynn is the 50th British town with a population of 10,096 persons, Narford is also a considerable town; it commences in the Great *Ouse* river near the harbour of Lynn, and terminates at the town of Narford.

Macclesfield and Leek. In 1796, it was said, that a canal between these places was in contemplation, with extensions thereof to the Staffordshire potteries, in all 29 miles, on which no locks were to be used. Macclesfield is the 61st British town with 8,743 inhabitants.

Maidenhead and Isleworth. In the year 1770, Messrs. *James Brindley* and *Robert Whitworth*, were employed by the city of London, to survey the line of a canal from the *Thames* river at Isleworth, to the same river again below Bolter's-lock near Taplow-mill, about 1 mile above Maidenhead-bridge, and at the lower end or termination of the 3d district of the *Thames and Isis* navigation; the length of this line is $19\frac{3}{4}$ miles with a rise of $71\frac{1}{3}$ feet. The canal was proposed to be 50 feet wide and 4 deep, with cuts to the *Thames* at Windsor, and near Laleham; in the first 5 miles 7 locks were to be built, and one in the remaining distance; the estimate of expence was 47,885l. A bill for this was brought into parliament, but the opposition of the landowners proved fatal to it; although, as appears, by an accurate measurement and section of the river between these two points made by the above engineers (see *Gentleman's Magazine for March* 1771), that the length of the river-navigation is $37\frac{3}{4}$ miles in this distance, and greatly obstructed by shallows, some only $2\frac{1}{2}$ feet deep in dry seasons. In the year 1791, this scheme was revived, and in 1794, Messrs. *Robert Whitworth* and *Robert Mylne* were employed to revise this line; their design has 12 miles of level at the upper end, and 10 of them straight; the canal to be 5 feet deep. The tolls at first proposed were $\frac{1}{2}$d. per ton per mile on all articles; out of this revenue, it was proposed to improve the river navigation between Mortlake and Bolter's-lock: and to raise the necessary sums on life annuities, so that after a fund was established for repairs and management, the canal might at length become free for the public use. At Bolter's-lock the *Reading and Maidenhead* canal was proposed to join this canal, by which the navigation from London westward would have been amazingly shortened and improved.

MANCHESTER ASHTON AND OLDHAM CANAL. Acts 32, 33, 38, 40, and 45 of Geo. III.—The general direction of this canal is nearly E. for about 7 miles in the counties of Lancaster and Cheshire; its eastern end is considerably elevated; its objects are the supply of Manchester and Stockport with coals, cannel, stone, lime, &c. and forming part of the intended direct communication between Liverpool, Manchester, and Hull, by means of the *Huddersfield* and other canals; by means of its Duckenfield branch it communicates with the *Peak-Forest* canal. Manchester is the 2d British town with 84,020 inhabitants, Stockport is the 29th with 14,830 persons, and Oldham the 35th with 12,024 persons, Ashton is also a considerable town, and the country round about is full of inhabitants. This canal begins in the *Rochdale* canal near Piccadilly street in Manchester, and terminates in the *Huddersfield* canal at Duckenfield bridge, in the parish of Ashton underline; from Duckenfield bridge is a branch of $\frac{1}{4}$ mile in length, over an aqueduct bridge on the Tame river at Walk-mill, into Duckenfield, there to join the *Peak-Forest* canal. There is a branch of 1 mile to Ashton town, another of $3\frac{3}{4}$ miles to New Mill in the parish of Oldham (but $2\frac{1}{2}$ miles distant from the town), from which last at Boodle-wood a branch proceeds over Water-Houses aqueduct on the Medlock brook, to Park collieries at Stake-Leach near Hollingwood, also in the parish of Oldham; from Droylsden, a branch of 6 miles proceeds to the end of the town of Stockport in Heaton-Norris parish, and from this last, a branch of 3 miles proceeds in a N.E. direction to Beat-Bank in Denton. The line has a rise of 152 feet between the *Rochdale* and *Huddersfield* canals. This canal is 33 feet wide at top, 15 feet at bottom, and 5 feet deep in water, except the summit pound which is made 6 feet deep to act as a reservoir; the locks are 80 feet long, and the boats carry 25 tons; there are three considerable aqueducts at Duckenfield, Ancoats, and at Water-Houses. This company were authorised by their first 4 acts to raise 170,000l., and a further sum by the late act; amount of shares 100l. The line of this canal was completed between Manchester and Ashton about the end of the year 1796, and in January 1797, the Stockport branch was opened; some of the works on this canal suffered by a flood in August 1799. The rates of tonnage are given in *Phillips*'s 4to. *History*, *Appendix*, p. 21. In 1802, we were told, that the shares in this concern were 20l. below par.

MANCHESTER BOLTON AND BURY CANAL. Acts 31,

and 41 of Geo. III.—The general direction of this canal is N.W. for about 11 miles in the county of Lancaster; its northern end is considerably elevated; its objects are a communication between the great manufacturing towns of Manchester, Bolton, and Bury, and the carriage of coals and other articles for their supply, and forming part of the line of communication between Manchester and the *Leeds and Liverpool* canal. Manchester is the 2d British town with 84,020 inhabitants, Bolton is the 32d with 12,592 persons, and Bury the 84th with 7,072 persons. This canal commences in the *Mersey and Irwell* navigation near the junction of Medlock brook (by which it communicates with *Bridgewater's* canal near the beginning of the *Rochdale*) at Manchester, and terminates at the town of Bolton, it has a branch of 4 miles in length to the *Haslingden* canal at the town of Bury. From the *Mersey and Irwell* navigation, is a rise of several locks to the bason in Salford parish; thence for about 4 miles is level; in the next 3 miles are 12 locks, the remainder of the line is level, including the branch to Bury; the whole rise is 187 feet. Previous to 1794, this canal was begun, and several locks were built for narrow boats, but on account of the branches connecting with wide canals which were proposed about that time, these were pulled up and rebuilt, and the canal widened, including some expensive deep-cutting and embanking; a want of skill or care appeared also, we are told, in the setting out of this canal by cutting deep through rocky ground which might have been avoided. There are two aqueduct bridges over the Irwell at Clifton-Hall and near Stocks, and one over the Leven at Long-fold, these are said to be 20, 16, and 10 yards high; the canal was, in 1799, supplied by a feeder from the Irwell at Bury, but in 1802, a reservoir and feeder also was found necessary in Radcliffe parish. In 1797, this canal was completed to Bolton, except the locks to connect with the *Mersey and Irwell* navigation; on the 17th of August, 1799, a great flood happened, which carried away the lower bank of this canal for 100 yards together on the summit-level, and another breach therein also happened, by which the navigation to Bolton, &c. was some time interrupted. This company were authorised by their first act to raise 97,000l., and a further sum by the late act. The rates of tonnage are for coals, lime-stone, stone, bricks, clay, &c. 2d. per ton per mile, if they pass a lock; but all these, except lime-stone, are to pass on the levels for ½d. per ton per mile; and when the water runs waste at the locks, lime-stone is also to pay only ½d. on any part; the tonnage at the entrance of the *Mersey and Irwell* navigation is also regulated by the first act. Passage-boats from Bolton to near Manchester are established; but when water has been scarce, the passengers have been required to walk past the locks to another boat on the lower pound to avoid the waste of lockage-water. About the year 1794, it was in contemplation to make a branch westward from Bolton, to connect with the *Leeds and Liverpool* canal at Red Moss near to Wigan, and to make a grand extension of the Bury branch eastward to the *Calder and Hebble* navigation at Sowerby-bridge, passing the grand-ridge between Littleborough and Rippondale by a tunnel of 5 miles in length! after passing a shorter tunnel of ½ a mile at lower Lomax near Heyford. In 1796, it was proposed to extend a branch from the bason in Salford parish to Oldfield-Lane in that town; and, in 1799, it was in contemplation to build an aqueduct bridge over the Irwell, and connect this canal with *Bridgewater's* canal, instead of locking down into the *Mersey and Irwell* navigation.

Market-Weighton Canal. Act 12 Geo. III.—The general direction of this canal is nearly N. for about 11 miles in the East Riding of Yorkshire; it has but little elevation above the sea; its objects are the conveyance of coals, deals, &c. to Market-Weighton and the surrounding country, the export of farming products, and the better drainage of the fen lands through which it passes; it commences in the tide-way in the *Humber* river (opposite to the *Trent* river) at Fosdyke-Clough, and terminates near Market-Weighton. It has a sea-lock next the *Humber*, from whence it is level to within a short distance of its northern end, where is a rise of 4 or 5 locks. Mr. *John Smeaton* was consulted on this line of canal and drainage, in 1767, at which time a branch of this canal to Pocklington was in contemplation; for the rates of tonnage, see *Phillips's* 4to. *History*, p. 270. This navigation was completed soon after the passing of the act.

Mawgan Canal. About the year 1775, a narrow canal was cut of 6 or 7 miles in length: from Port Mawgan near Trenance on the N.W. coast of Cornwall, to within 3 miles of St. Columb Major, it was intended for bringing up coals and sea-sand for manure, and for carrying down china-stone and clay, substances found in St. Dennis and St. Stephens, and used in the Staffordshire potteries; but after several of the adventurers were ruined, the scheme was totally abandoned.

Medina River. The direction of this navigation is south, and nearly straight for 4½ miles, in the Isle of Wight in Hampshire; the tide flows through its whole length; its object is the supply of Newport and the central parts of the island with coals and other articles; it commences at Cowes harbour (opposite *Southampton Water*), and terminates at Newport bridge.

Medway River (*lower district.*) Acts 32 and 42 of Geo. III.—The general direction of this navigation is nearly S.W. for about 27 miles by a bending course in the county of Kent; it is but little elevated in any part; its objects are the import of coals, deals, and other articles, and the export of Kentish-Rag lime-stone, fullers-earth, farming-produce, &c. near its northern termination, it connects with the east Swale or tide-way passage, of about 15 miles in length south of Sheppy island, connecting with the *Thames* near Whitstable; and, at Nicholson's ship-yard in Strood it is joined by the *Thames and Medway* canal. Chatham is the 46th British town with a population of 10,505 persons, Maidstone is the 66th with 8,027 persons, and Rochester is the 90th with 6,817 persons, Sheerness, Queenborough, and Milton, are considerable towns on or near this navigation, which commences in the river *Thames* at the Nore, and terminates in the upper *Medway* navigation at Maidstone bridge. Over this river at Rochester, there is a stone bridge of 11 arches and 550 feet long. At Chatham is a very considerable naval arsenal. The powers of the above acts for repairing and levying of tolls, extend no further down this river than from Maidstone to the tide-way at Aylresford bridge.

Medway River (*upper district.*) The general direction of this part of the river is S.W. for about 12 miles in the county of Kent; it is not much elevated in any part; its objects are the import of coals, deals, &c. and export of lime-stone, fullers-earth, farming-produce, &c. besides Maidstone, mentioned above, Tunbridge is the only considerable town on this line; it commences in the lower *Medway* navigation and terminates at the town of Tunbridge. In 1802, the *Medway and Rother* canal was proposed to connect with this river at Yalden-lees.

Medway and Rother. In the year 1801, a survey and estimate was made by Mr. *Sutherland*, for a canal from the *Rother* river intended navigable branch at Small-Hithe, to the *Stour* river at Canterbury (at the S. end of the proposed *Canterbury and Nicholas-bay* canal), with a branch thereof

to the *Medway* river at Yalden-lees, through the counties of Suffex and Kent; its objects were the fupply of the interior country with coals and other articles, the export of timber and farming products, and forming a communication between the fouth coaft at *Rye-harbour* and the *Thames* river, &c. Forty-ton boats were intended to be ufed, and the canal to be 4 feet deep. The fummit was found to be about 100 feet above the fea, and nearly 50 miles of the line was to be upon one level.

Menai Streight. This ftreight feparates Anglefea ifle from North Wales, and has nearly a N.E. direction for about 16 miles, through which the tide flows; it extends from Caernarvon bay at Abermenai Ferry to Lavan Sands; Caernarvon and Bangor are confiderable towns on this line. In 1801, and 1802, it was in contemplation to build a caft-iron bridge over this ftreight at Swelly rocks near Porthacthavy Ferry not far from Bangor.

Mersey and Irwell Navigation. Acts 7 Geo. I. and 34 Geo. III.—The general direction of this navigation is nearly eaft, by a crooked courfe of 50 miles in the county of Lancafter, and fkirting the county of Chefter; the firft 20 miles being by a moft fpacious eftuary of the *Merfey* river; it is not greatly elevated in any part; its objects are moft important, particularly in the immenfe trade between Liverpool and Manchefter, and Hull, alfo by four different routes acrofs the grand-ridge; the navigations immediately connecting therewith are, at Ellefmere-port in Netherpool, where it is joined by the *Ellefmere* canal; at Wefton by the *Weaver* river; at Runcorn-Gap, and again at Manchefter (by the Medlock Brook), by *Bridgewater*'s canal, befides being croffed thereby on Barton aqueduct; at Fidlers-ferry, and alfo at Sankey Brook, by the *Sankey* canal; and at Manchefter, near the junction of Medlock Brook, by the *Manchefter Bolton and Bury* canal: befides which, the following commence very near to this navigation, although they do not actually lock down into it: viz. the *Leeds and Liverpool*, at the bafon in Liverpool, the *Trent and Merfey*, at Prefton Brook, and the *Rochdale*, at Manchefter; to which alfo the *Manchefter Afhton and Oldham* ought to be added, although a very fhort fpace of two other navigations muft be paffed through before you can reach the Irwell therefrom. Manchefter is the 2d Britifh town, with a population of 84,020 perfons; Liverpool is the 4th, with 77,653 perfons; and Warrington is the 45th, with 10,567 perfons. This navigation commences in the Irifh Sea, at Wallazy, about 3 miles below Liverpool, and terminates at the bridge between Manchefter and Salford: but the powers of the act, as to improving the river and collecting the tolls, at firft extended no lower than Bank-key, near Warrington, and fince to Runcorn Gap. The winding courfe of the river has been fhortened in feveral places by fide-cuts acrofs the loops, and locks and wears have been erected in feveral places, the rife in the whole length being about 70 feet; thefe rivers are fubject to fudden and violent floods, which have at times deftroyed feveral of the navigation works; in Auguft 1804 a new fide-cut was completed, for fhortening the courfe of the navigation, and avoiding the fhallows in the river; between Warrington and Runcorn Gap it croffes the *Sankey* canal. The famous wet-docks at Liverpool are an appendage to the *Merfey* navigation, and are indeed a part of that river, from not being excavated in folid ground, where houfes formerly ftood, as they did on the fite of the *London Docks*; but all of them, except the old Dock, which was a natural creek or pool, have been formed in the front of the town, by embankments in the river, which is here ¾ of a mile wide. At the lower or northern end of thefe docks, as we viewed them in 1797, is a large inlet or walled tide-bafon, which connects with the river, and is dry at low water, from the S.E. corner of this is the entrance of *St. George's Dock*, which was the third large dock that was made, and is nearly a parallelogram, of 250 yards long and 100 wide, its quay being 670 yards long, its gates are 25 feet high and 38 feet wide, and it coft about 21,000 l. Paffing foutherly, we next arrive at a dry bafon and wharf, called the old quay, for the flatts or veffels belonging to the *Merfey and Irwell* company, which are about 32 in number; and fome diftance fouth of this is another large inlet to a fpacious dry bafon for fhips: from the north end of this bafon are other gates into *St. George's Dock*, above mentioned, and ftraight forwards is the entrance to the *Old Dock*, or the firft that was built, and is wholly within the town; this dock forms an irregular parallelogram, of 200 yards long and about 80 yards wide, its gates being 23 feet high and 34 feet wide; it is lined with bricks, but all the other dock, bafon, and pier walls are of beautiful hewn ftone. From the fouth-eaft corner of the laft defcribed dry-bafon is the entrance to *Salt-Houfe Dock*, which was the fecond made, is an irregular trapezium, of 21,928 yards in area, and has 640 yards in length of quay, its gates being 23 feet high and 34 feet wide. A confiderable diftance fouth of the laft dry-bafon is an inlet to a fmall wet-dock which belonged to the late *duke of Bridgewater*, and is ufed by the flatts which trade between Manchefter and Liverpool, by *Bridgewater*'s canal, thefe carry 50 tons, and 42 of them belonged to his grace. Proceeding further along the fhore fouthward, we arrive at another inlet and dry-bafon, from the north fide of which is the entrance to the *King's Dock*, the fourth which was made (being finifhed in 1788), and is a regular parallelogram, of 290 yards long and 90 wide, the gates thereof being 25 feet high and 42 feet wide. From the head, or eaft end of the laft dry-bafon is the entrance to the *Queen's Dock*, which was the fifth and laft that was made, being alfo the largeft and moft complete of the whole, its length is 270 yards, breadth 130, its gates 25 feet high and 42 feet wide, and it coft about 25,000 l. An attempt was made to form a dock in the fite of the *old Dock*, as long ago as 1561, but it was not until the year 1710 that the firft act was obtained, of which there are feveral, for building and regulating the prefent docks. In 1799 application was made again to parliament for powers to build two more large docks, one of them more northerly than any of thofe we have defcribed, and the other in front of *Salt Houfe* dock. The whole extent of thefe docks and quays will then be nearly 2 miles by the fide of the *Merfey*! With the two dry bafons laft defcribed, feveral convenient graving-docks connect, for the building or repair of fhips, fome of the latter are long enough to hold three fhips in length. The fpace between thefe graving-docks and in front of the docks, is principally occupied by timber-yards. The draw-bridges over the entrances to fome of thefe docks are among the largeft and moft complete in England: Mr. *Morris* erected and has the care of them and the docks. On the fouth fide of the *King's Dock* is a fpacious warehoufe 210 feet long and 180 wide, for tobacco, of which it will contain 7000 hogfheads. The fpring-tides here rife 21 feet, but the neap-tides only 12 feet, on which account large fhips cannot enter or leave thefe docks for fome days during the loweft tides. Fires and fmoking of tobacco are on no account allowed on board of fhips in thefe docks, nor lighted candles, except in proper lanthorns, and no gunpowder is allowed on board; by a ftrict attention to which rules, no fire has ever happened in thefe docks. In the year 1797 the tolls in thefe docks amounted to upwards of 13,300 l. annually, and their yearly expences to 5,100 l. but a debt of 113,419 l. ftill remained on them: for many of the above particulars we are indebted to *W. Mofs's Liverpool Guide*. In the year 1737

Worſley Brook was intended (and an act paſſed 10 Geo. II.) to be made navigable; and, in 1758, a branch of *Bridgewater*'s canal was intended to join at Hollin Ferry, but neither of theſe has been executed. In 1771 Mr. *James Brindley* propoſed an aqueduct-bridge over the eſtuary of the *Merſey* river, for the uſe of the intended *Liverpool and Runcorn* canal; and in 1801 Mr. *Ralph Dodd* tried to perſuade the adoption of a road-bridge over the ſame at Caſtle Rock near this place, 412 yards long, which he ſtated might be built for 47,000l. In 1799 it was ſuggeſted that a tunnel might be made under the *Merſey* at Liverpool to the oppoſite ſhore in Cheſhire, ¾ of a mile; in the ſame year it was in contemplation to build an aqueduct over the Irwell, for the uſe of the *Mancheſter Bolton and Bury* canal, to enable it to join *Bridgewater*'s canal; and in 1804 it was propoſed to bring the *Weaver* navigation to Weſton Point on this navigation, by a new ſide-cut, near that river from Frodſham, to avoid the ſhallows near the junction of the rivers. In 1758 the price of carriage on this navigation, between Liverpool and Mancheſter was 12 s. per ton, but on the completion of *Bridgewater*'s canal it fell to 6 s. per ton.

Milford Haven. This famous eſtuary and harbour for large ſhips, has nearly an eaſt courſe, for about 17 miles, in the county of Pembroke, in South Wales, commencing in St. George's channel, and terminating near Landſhipping ferry, where it is joined by the *Dougledge* and *Cleddy* rivers: it has alſo creeks or branches extending to Pembroke, to near Carew Caſtle, to Creſwell, to Nangle, &c.

Monkland Canal. The general direction of this canal is nearly eaſt, for about 11½ miles in the county of Lanerk in Scotland, its eaſtern end is conſiderably elevated; its objects are the ſupply of Glaſgow, Paiſley, &c. with coals from Monkland collieries, and the export of farming products. It commences in the baſon of the branch of the *Forth and Clyde* canal, and thereby communicates with the *Clyde* river, and the *Edinburgh and Glaſgow* canal. Glaſgow is the 5th Britiſh town, with a population of 77,385 perſons. In 1803 the *Glaſgow and Saltcoats* canal was propoſed to connect with this at Glaſgow.

Monmouthshire Canal. Acts 32, 37, and 42 of Geo. III.—The general direction of this compound of canals and rail-ways is nearly north, for 17¾ miles, in the counties of Monmouth, and Brecknock in South Wales; its northern ends are very greatly elevated; its object is the export of coals, lime, and iron from the country through which it paſſes; near Pontypool it is joined by the *Brecknock and Abergavenny* canal, at Pill-Gwenlly it joins to the *Sirhowy* tram-road (by means of the *Uſke* river), and at Count-y-Billa farm, and at Riſca, it joins the ſame again by different branches belonging to this company. Newport and Pontypool are conſiderable towns on this line. This canal commences in the tide-way of the *Uſke* river, near to the *Severn*, at Pill-Gwenlly, and terminates by a rail-way extenſion at Blaen-Aſon iron furnaces, having alſo a principal branch of canal from the line at Crynda-Farm, near Malpas, and continued by a rail-way to Beaufort iron-works, 21 miles: from this branch are rail-way branches to Sorwy furnace, 1¼ mile, to Nant-y-glo works, 6¼ miles, and another to the Sirhowy tram-road at Riſca: from the line near Pontypool is a railway branch, 1 mile, to Tronſnant furnace, and another, of ½ a mile, to Blaen-Dir furnace. From the *Uſke* river to Pont-Newydd, 12¼ miles, is a riſe of 447 feet by the canal, and thence to Blaen-Aſon, 5¼ miles, is a riſe of 610 feet by the rail-way: from Crynda-Farm to Crumlin bridge the canal branch riſes 358 feet in 11 miles; thence for 3 miles to the rail-way bridge over Ebwy river, 3 miles, the rail-way has a riſe of 139 feet, and thence to Beaufort, 7 miles, it has a riſe of 480 feet; the Nant-y-glo branch has a riſe of 518 feet, along the ſide of Ebwy-Frach river. The locks are 60 feet long and 10 feet wide, their paddle-holes are, in ſome of them, united in the breaſt of the lock, and no ſheet-piling, or inverted arch has been made below the lower gates. Much deep-cutting and embankments have here been neceſſary, to obtain the proper ſlopes for the rail-ways and inclined planes. Mr. *Thomas Dadford* jun. is the engineer: in February 1796 the canal was completed from the *Uſke* to Pontypool, and in the ſame year the Beaufort branch was completed. This company were authoriſed by their different acts to raiſe 275,330l. in 100l. ſhares: in 1802 theſe divided 2l. 12s. 6d. each annually; it is provided, that after the profits amount to 10 per cent. and 1000l. is accumulated as a fund, the tolls are to be reduced, firſt on coals, ſo as to keep the profits within that amount. The tolls and exemptions are various, and may be conſulted in *Phillips's* 4to. *Hiſtory*, *Appendix*, p. 18 and 19, where tolls are ſpecified for cattle paſſing on the rail-ways. Nine miles of the *Sirhowy* tram-road was made by this company, who receive the tolls thereof, as alſo 110l. per annum from that company, on account of the junctions therewith: to the *Brecknock and Abergavenny* company this company paid the ſum of 3000 l. for the benefit of their junction herewith, and their taking the ſame tolls only on goods paſſing on it from this canal as are charged hereon. Rail-way branches may be made to any works within 8 miles of this canal or its branches. In the year 1805 it was propoſed to continue this canal lower down the *Uſke* river, to avoid its imperfect navigation.

Montgomeryshire Canal. Act 34 Geo. III.—The general direction of this canal is nearly S.W. for 27 miles in the county of Salop and of Montgomery in North Wales; it is conſiderably elevated, particularly its ſouthern end; its objects are the ſupply of the country with lime, the export of its farming products and of coals, ſlate, free-ſtone, iron, lead, &c. from different parts near the line: it connects with the *Severn* river at Welſhpool. Welſhpool, Montgomery, and Newton are conſiderable towns on or near this canal: it commences in the Llanymynach branch of *Elleſmere* canal, at Portywain lime-works in Llanyblodwell, and uniting with the ſame again near Verniew river in Llanymynach, it terminates at Newtown: it has a cut of 3¼ miles to the *Severn* river at Welſhpool and to Guilsfield. From the *Elleſmere* branch to Newtown is a lockage of 225 feet: the Guilsfield cut is level. Mr. *Thomas Dadford* jun. is the engineer. In Auguſt 1797, 16 miles of the canal were finiſhed and opened from the *Elleſmere* branch to Garthmill near Berriew. The company were authoriſed to raiſe 92,000 l.; the amount of each ſhare 100l. The water of Lledan Brook is to be taken to ſupply this canal for 24 hours weekly, from Saturday to Sunday evening; the company are bound to purchaſe certain mills, if their trade is injured by the canal: and certain creditors on turnpike tolls near the canal are alſo indemnified: the profits are not to exceed 10 per cent. but the tonnage is to be reduced, but not ſo as to bring the profits below 8 per cent.: the rates of tonnage and exemptions are various: ſee *Phillips's* 4to. *Hiſtory*, *Appendix*, p. 151 and 152. About the year 1794 the *Welſhpool and Leominſter* canal was propoſed to join this near Welſhpool.

Neath Canal. Acts 31 and 38 Geo. III.—The general direction of this canal is nearly N.W. for about 14 miles in the county of Glamorgan in South Wales; and its northern end is conſiderably elevated; its object is the export of coals, iron, lime-ſtone, &c. from the mines and works near the line; which commences in the tide-way of the *Neath* river, at Giants-grave pill in Briton's-Ferry, and terminates in the *Aberdare* rail-way branch at Abernant near Furno

Vaughan: being joined near Briton's Ferry, in the *Neath* river, by the *New Chapel* canal. Neath is the only considerable town on this line; near Merlin's Court is an aqueduct over the Neath river. This company were authorised to raise 35,000l.; they are authorised to make rail way branches to any place within 4 miles of the line, by consent of the land-owners. In 1798 this canal was nearly finished, except about two miles at the lower end. Here is a singular provision, that the rates of warehouse-room are to be the same as are charged by the *Staffordshire and Worcester* company at the Stourport warehouses.

NEATH RIVER. The general direction of this navigation is nearly N. for about 4 miles in the county of Glamorgan, in South Wales: the tide flows through its whole length from Swansea bay to Neath bridge; at Giants grave pill near Briton's Ferry it is joined by the *Neath* canal, and near Briton's Ferry by the *New Chapel* canal; its chief objects are the supply and trade of Neath, and the export of the coals and iron brought down by the canals.

NEN RIVER (*lower district.*) Acts Geo. II., and 34 of Geo. III.—The general direction of this navigation is about S.W. by a very crooked course of nearly 75 miles in the counties of Cambridge and Huntington, and skirting those of Lincoln and Northampton; this is by what appears to have been its ancient course through the Fens, beginning in the tide-way at Peter's point about 9 miles below Wisbeach, passing that town, where is a bridge built of stone with one flat semi-elliptic arch of 70 feet span; and turning south-eastward by an ancient course (which is now rendered useless to navigators by the *Wisbeach* canal, which joins this river at Wisbeach and again at Outwell), to Outwell and Apwell, thence to March and Benwick, thence through Ramsey, Ugg, and Whittlesea Meers, through Horsey-bridge, and Standground sluice to Peterborough, and thence by the regular channel of this river to the commencement of the upper *Nen* navigation at Thrapston; in after times, a navigable course has been opened, for part of the waters of this river through Well-Creek, about 5 miles in length, from near Outwell-church to the Great *Ouse* river at Salter's-Load; another from Standground (1½ mile below Peterborough) through Catt-Water and Shire Drain of about 24 miles in length to the *Nen* river again at Gunthorpe-sluice (about 6½ miles below Wisbeach), this last having a cut of about 2 miles in length from it into the old *Welland* river near Crowland; in 1490, bishop Moreton cut a new straight course 40 feet wide and 13 miles long, called Moreton's Leam, for a part of these waters, from Standground sluice (about 2 miles below Peterborough) to near Guyhirne, and thence 3 miles by an old channel to the *Nen* again near Wisbeach; also, at Benwick this river is joined by the Benwick-Meere branch, of the Great *Ouse* river. The above will serve to give some idea of the principal lines of navigation belonging to this river through this surprizing country; but as all the rivers, and all drains almost in the fens are embanked on both sides, and owing to the deficiency of fall are almost still water, there are a great number of smaller navigable branches intersecting and crossing each other in all directions, so that it would be in vain for us to attempt to describe them. The powers of the commissioners under the above acts, extend only about 30 miles downwards to Peterborough bridge; the navigations through the fens are preserved by the fen corporation in maintaining their drainage works. In 1721, Mr. *Nathaniel Kinderley* recommended the cutting of a new channel or outfall for this river (as has been since successively practised by him on the *Dee* river at Chester) from the mouth of Shire-drain at Gunthorpe-sluice straight along the N.W. shore for 2 miles to Peter's point; and the work was begun, but the mistaken notions of the people of Wisbeach then, and till lately, prevented its completion: we are glad, however, to hear, that the same is likely now to be soon accomplished, and a greater depth of water obtained in this river, and through Cross-keys wash to Lynn and Boston deeps. By the act for *Wisbeach* canal 34 Geo. III., all vessels passing out of or into that canal from the *Nen* are to pay 3d. per ton, out of which 100l. is to be paid annually to the commissioners under the above acts for improving this river above Peterborough, and the remainder is to be applied to deepening and improving the same between the *Wisbeach* canal at Outwell and the *Ouse* river at Salters-Load. Boats which have paid the above toll are to pass toll free at Salters Load, and Standground sluices on this river.

NEN RIVER, (*upper district.*) The general direction of this navigation is nearly S.W. for about 23 miles, in Northamptonshire: it is not greatly elevated; its objects are the supply of Northampton and the surrounding country with coals, deals, &c. and the export of agricultural productions. The communication between Lynn, London, Liverpool, Manchester, &c. which it now effects is also important. Northampton is the 85th British town with a population of 7,020 persons, Wellingborough, Thrapston, and Higham-Ferrers, are also considerable towns on or near this river; it commences in the lower *Nen* navigation at Thrapston, and terminates at the rail-way branch of the *Grand Junction* canal at the town of Northampton, where also it is to be joined by the *Leicestershire and Northamptonshire Union* canal. This navigation has been improved by a great number of side-cuts and pound-locks by the side of the river in different places; it was completed and opened to Northampton on the 7th of August 1761. About the year 1793, the *Leicester and London* canal was proposed to cross this river near Wellingborough.

Newark and Bottesford. In the year 1793, a canal was intended from the *Dean* river at Newark to the long level of the *Grantham* canal at Stainwith, passing near the town of Bottesford. In the *Grantham*, act 33 Geo. III., the tolls are provided that are to be paid at the junction of these canals, if this is ever executed.

Newcastle and Carlisle. In the year 1795, Mr *William Chapman* surveyed the line for a canal from the *Tyne* river at Newcastle to the *Eden* river at Carlisle, through Durham, Northumberland, and Cumberland, crossing the grand-ridge for a connection between the east and west seas; and having a collateral branch of narrow canal and inclined-planes to the elevated mining districts of Weardale and Teesdale forests, &c. the estimate being 355,067l. On the rejection or suspension of this scheme, a canal from *Newcastle to Haydon-bridge* was proposed as below.

Newcastle and Haydon-Bridge. In 1796, and again in March 1802, it was in contemplation to make a canal nearly following the course of the Tyne river, between Newcastle and Haydon, in Northumberland and Durham.

Newcastle and Maryport. Some years previous to 1801, a canal was projected between the tide-way in Maryport harbour and the *Tyne* river at Newcastle, crossing the grand ridge, and passing between the two seas, though Cumberland and Durham counties: a bill for the same was brought into parliament, but rejected, owing to the opposition that the favourers of another scheme gave to it: in 1801, the scheme was again revived, but nothing effectual has been done towards its adoption.

NEWCASTLE (*under-line*) CANAL. Act 35 Geo. III.—The general direction of this navigation is nearly west, by a very bending course of 3 miles, in the county of Stafford: its objects are the bringing of Caldon lime for manure,

and the export of coals and farming products: it is considerably elevated. Newcastle is a considerable town, and its neighbourhood very populous. This canal commences in the *Trent and Mersey* canal (near to the end of the Caldon branch) at Quinton's Wood, in Stoke, and terminates in the *Newcastle under-line Junction*, at the south-east corner of Newcastle town. It was completed in a short time after the act was obtained, the company being authorised to raise 10,000 l.; the amount of shares therein is only 50 l. each. The rates of tonnage and wharfage are on coals, lime-stone, and iron-stone 1½d. per ton per mile, on all other goods 2d. per ton per mile, but for less than a ton of any article in a boat 6d. Between December and the 1st of April this company may take flood waters from the Trent river.

NEWCASTLE (*under-line*) JUNCTION CANAL Act 38 Geo. III.—The general direction of this canal is about N.W. for a short distance, in two detached parts, in the county of Stafford: its western ends are much elevated, and terminate near the grand ridge on its eastern side: its object is the export of coals and agricultural produce. Newcastle is a considerable town on its line. It commences in the *Newcastle-under-line* canal, at the S. E. corner of that town, and terminates its eastern part in the canal of Sir *Nigel Bowyer Gresley*, near the S.W. corner of the town; its western part commences in *Gresley's* canal above mentioned, near Apedale, and extends to Partridge-Nest collieries, with a branch to Bignel-End collieries. This company were authorised to raise 12,000 l., the amount of their shares being 50 l. only: provision is made in the act for inclined-planes and water-levels, or rail-ways, with engines to raise water or draw trams, &c. in case any of these should be found more eligible than a canal with locks, in any part. Pleasure boats to pay for 6 tons if they pass any lock. In 1796, the *Commercial* canal, for 40 ton boats, between the *Ashby* and *Chester* canals, was proposed to occupy or pass through the line of this canal, when enlarged.

NEW CHAPEL CANAL. The general direction of this canal is east, by a bending course of about 3½ miles, in the county of Glamorgan, in South Wales; the greater part of it is cut through a morass, but little above the level of the tide-way in which it commences, in the river *Neath*, near Briton's Ferry (near the entrance of the *Neath* canal), and terminates at New Chapel, near Swansey: it is the sole property of the owner of the land, and for whose improvement, by draining and otherwise, it was principally undertaken.

Newport and Stone. In June 1797, it was proposed to make a canal from the *Donnington Wood* canal (the marquis of *Stafford's*) at Pave-lane, near Newport, by Eccleshall, to the *Trent and Mersey* canal, near Stone, a course of about 18 miles, in the counties of Salop and Stafford, crossing the grand-ridge; a branch was proposed to Market-Drayton: its object was the opening of a direct communication between Shrewsbury, and other places on or near the upper parts of the *Severn*, and the *Trent and Mersey* canal, for supplying the intermediate country with coals and lime, &c. In 1705, the *Tern-bridge and Winsford* canal was proposed, and intended to pass through nearly the same ground as the middle parts of this canal; as was also the *Sandbach* on an other occasion.

NEWRY CANAL (*Ireland*). This canal, from the tideway at Fadham point to the town of Newry, was completed under the direction of Mr. *Golborne*, in February 1761, after being two years in hand, by which brigs of 80 or 100 tons burthen can come up to Newry; it was intended to extend this to the *Blackwater* navigation, for conveying the Dungannon and Drumglass coals to Dublin; and the Irish parliament, between 1753 and 1771, granted different sums of the public money for this purpose, amounting to 11,434l. but the work then was far from being completed.

NITH RIVER. The course of this river (sometimes called the Nid) is nearly north for about 9 miles, between Dumfries and Kirkcudbright counties, in Scotland; the tide flows through its whole length, and its object is the supply of Dumfries, (the 79th British town, with 7,288 persons); it commences in Solway Firth, and terminates at Dumfries bridge, which is of stone, with 13 arches. In 1760, Mr. *John Smeaton* was consulted on the encroachments by jetties of stakes and stones for gaining land, that had been made at Cargin, Lagal, and Netherwood, on this river, and recommended the removal of some of these works at the projecting points of the river.

NOTTINGHAM CANAL. Act Geo. III.—The general direction of this canal is nearly N. W. by a crooked course of about 15 miles, in the county of Nottingham; it is not very greatly elevated: its objects are the export of coals from the several mines near it, and of farming products, importing lime, deals, &c. Nottingham is the 17th British town, with a population of 28,861 persons. This canal commences in the river *Trent*, near Nottingham (opposite to the junction of the *Grantham* canal), and terminates in the *Comford* canal, near Langley bridge, and near to the termination of the *Erewash* canal: near to its southern termination it is joined by the *Trent* canal or side-cut (from the *Trent and Mersey* canal). A reservoir is made near Amsworth for the supply of this canal, and has a self-regulating sluice which lets out near 3000 cubic feet of water per hour for certain mills and the *Erewash* canal. In 1802, this canal was completed.

NUTBROOK CANAL. Act 33 Geo. III.—The general direction of this canal is nearly N. W. for 5 miles, in the county of Derby: it is not greatly elevated: its object is the export of coals from the mines near the line; which commences in the *Erewash* canal, near Stanton, and terminates at Shipley colliery; it has a branch to West Hallam collieries. Sir Henry Hunloke and Edward Miller Mundy, esq. were authorised to raise 19,500 l. between themselves, in 100 l. shares; their profits hereon are not to exceed 8 per cent.; and proprietors of adjoining lands may make side branches thereto: the particulars of the tonnage rates are very long, including some regulations with the *Erewash* company, &c. See *Philips's* 4to. *History, Appendix*, p. 104 and 105.

OAKHAM CANAL. Acts 33 and 40 Geo. III.—The general direction of this canal is about S. E., by a crooked course of 15 miles, in the counties of Leicester and Rutland: its southern end is considerably elevated, crossing the Tilton and Burley branch from the grand-ridge: its objects are the supply of Oakham, and the country through which it passes, with coals, deals, &c., and the export of agricultural products. Oakham and Melton-Mowbray are considerable towns on this line, which commences in the *Leicester and Melton-Mowbray* navigation, at Melton-Mowbray, and terminates at the town of Oakham. From the *Leicester and Melton-Mowbray* navigation to Edmondthorpe, 8½ miles, it has a rise of 126 feet; the remaining 6½ miles to Oakham are level, and it is fed by a reservoir for flood-waters in Langham, and another in Saxby. The engineers were Mr. *William Jessop* and Mr. C. *Stavely*, jun. In November 1800, this canal was opened from Melton-Mowbray to Saxby bridge, and in January 1803, the whole was completed. This company was authorised to raise 86,000 l. in 100l. shares. The rates of tonnage and wharfage, with the exceptions therefrom, may be seen in *Phillips's* 4to. *History, Appendix*, p. 106 and 107, but to which the last act made an addition,

and the *Leicester and Melton-Mowbray* act, 40 Geo. III., also contains some regulations affecting the tolls at the entrance to this canal. Earl Winchelsea is to be paid 15l. annually, in lieu of his customary dues on coals sold in Oakham town.

Ouse River (*Lewes lower Navigation*). Act 31 Geo. III. The general direction of this navigation is nearly north, for near 9 miles, in the county of Sussex: the tide flows through its whole length: its objects are the import of coals, deals, &c. and the export of farming products. Lewes is a considerable town on this navigation; which commences in the English channel, at Newhaven harbour, and terminates in the upper *Ouse* navigation, at Lewes bridge: the meadows, called Lewes and Laughton Levels, near this river, were subject to be overflowed, and it is part of the object of the above act to embank the river and its tributary streams, and to erect proper sluices, and cut drains for the improvement thereof; part of the money for which draining purposes, is to be raised by the commissioners of sewers, under the act of 23 Hen. VIII., by different rates per acre on each of the five districts into which the levels are by this act divided, but the works are to be performed by the trustees appointed by this act, who, in 1802, completed the straightening and deepening of the course of the river, so that the tides flowed higher and ebbed lower than before at Lewes bridge, and to which place vessels drawing 4 feet of water can now come up. The tolls on articles navigated on any part of this river are to be, for manures not exceeding 2d. per ton, for road-materials 3d., and for all other goods 4d. per ton, empty boats to pass toll free; these tolls are not to be lowered (except road-materials to 2d.), so long as 6,000l. of the money borrowed on the credit of these tolls and the acre-taxes, remain undischarged; the tolls are intended hereafter to be so reduced, that one-third of the whole expences of maintaining the navigation and drainage works shall be paid by the acre-taxes, and two-thirds by the tolls on the river; the acre-tax is, however, to make up the deficiency, if the above tolls are inadequate; lands below Newhaven bridge are not to be taxed, but to maintain their own banks. In the year 1762, Mr. *John Smeaton* was consulted about improving the navigation and drainage of this river. About the year 1793, a new pier was built to protect the harbour of Newhaven, and the entrance of this river; in 1802, it was proposed to add a new groin thereto to the westward, for the further security of vessels; and, in 1804, it was in contemplation, by large stones from the neighbouring cliff, to extend a rough unwalled pier much further out into the sea, for the security of vessels on this coast.

Ouse River. (*Lewes upper Navigation*). Act 30 Geo. III.—The general direction of this navigation is nearly north-west, by a bending course of about 22 miles, in the county of Sussex: it is not much elevated above the level of the sea: its objects are the import of coals, deals, &c. and carrying chalk and manures to the lands, and the export of their agricultural products. Lewes and Cuckfield are considerable towns on this line; it commences in the lower *Ouse* navigation, at Lewes bridge, and extends to Hammer bridge, near Slaugham, with a branch to Offham chalk-pit, in Hamsay; the depth of water in every part is to be made 3½ feet: the boats to be 50 feet long and 12¼ feet wide, and are not to pass locks with less than 10 tons of lading. This company were authorised to raise 25,000l. in 100l. shares, and the works were not to commence until 10,000l. of this was subscribed, and 10 per cent. thereon actually paid: it is to that public spirited and worthy nobleman lord *Sheffield* that the country are in a principal degree indebted for bringing about this useful measure. From Lewes bridge to Barcome mill there was an old and imperfect navigation for small boats; on this part of the line, the rates of tonnage are to be, on manures, road-materials, timber, grain, &c. ½d. per ton per mile, and on all other goods 1d. per ton per mile; on the remainder or new part of the line, manures, &c. as above, are to pay 1d. and other goods 1½d. per ton per mile. Empty boats to pay 1s. for passing each lock, and pleasure boats 3d. below and 6d. above Freshfield bridge for passing locks. Between Old Eye, in South Malling, and Land-Port, no toll is to be taken, on goods carried no further. Branches may be made to any place within 2000 yards of this river, on which the powers of the commissioners of sewers (23 Hen. VIII.) still continue. In 1801, it was proposed to make an extension of the *Surry iron rail-way* to join this navigation at Linfield. In 1802, the navigation was not completed up to Hammer bridge; but, in the following year, it was said that a new act for further powers for that purpose was in contemplation.

Ouse (*great*) River. The general direction of this river is nearly S. W., by a crooked course of about 84 miles, in the counties of Norfolk, Cambridge, Huntington, and Bedford, and skirting Suffolk for a short distance: this course through the fens being from the tide-way in Lynn deeps, (2 miles below that town), past Lynn, Telney, Salter's Load, Denver-sluice, Rebeck, Little port chair, Ely, Harrimere, Hermitage-sluice, Erith, and thence by the regular channel of this river to Bedford. Soon after the year 1630 (in consequence of a law of sewers of the 13th of January, 6 Charles I.) the old Bedford river, (a straight cut, of 21 miles long and 70 feet wide), was made, between Hermitage-sluice and Salter's-Load, for conveying part of the waters of this river; and in 1652, the scheme of Sir *Cornelius Vermuyden* for another navigable cut nearly parallel to the last was carried into effect, (under the authority of an act of Cromwell, 1649, confirmed afterwards by 15 Charles II. establishing the fen corporation); this last, called the New Bedford river, is 20 miles long and 100 feet wide, from Hermitage sluices to Denver's sluice, both these new cuts falling into the great *Ouse* river again, at Salter's-Load and Denver's sluice (which are within about a mile of each other, and 17 miles from Lynn); besides these, part of the waters of this river make their way by a navigable cut of about 12 miles in length, from Hermitage into the *Nen* river at Benwick. In 1725, Mr. *Thomas Badslade* mentioned, and, in 1751, Mr. *Nathaniel Kinderley* strongly recommended, another shorter cut between Eaubrink and Lynn, for straightening the course of this river, for which the acts of the 35, 36, and 45 of Geo. III. have been passed, called the Eaubrink cut, and on which Mr. *Robert Mylne*, sir *Thomas Hyde Page*, and captain *Joseph Huddart* are employed as engineers; this cut was, in September 1804, marked out, and is intended to be 296 feet wide at the east end, 204 feet at the west end, and about 2¾ miles in length, making easy bends into the river at each end, with banks on each side, at a distance from the cut, 6 feet higher than the ordinary tides, of 15 feet rise, with an embankment and sluice across the old channel, above the east entrance of the new one; which important works ere long, we hope, will be completed. Near the harbour of Lynn this river is joined by the *Lynn* river; at Salter's-Load, by a branch of the *Nen* navigation (called Well Creek); between Salter's-Load and Denver's sluice it is joined by *Stoke* river; at Rebeck the little *Ouse* joins; at Prick willow the *Lark* river joins; near Barkway chapel the *Soham-Lode*; at Harrimere, the *Cam* river joins; and at Temsford the *Ivel* river also joins: the whole of the rivers and large drains in

these fens being embanked and nearly level; there are many others of them navigable for short distances besides the above. Lynn is the 50th British town, with a population of 10,096 persons: Downham, Ely, St. Ives, Huntingdon, St. Neots, are also considerable towns on this line. Denvers dam and sluice, with 5 eyes or arches, was built across the great *Ouse* river, just above the entrance of the new Bedford-river, in the year 1651; in 1713, the water having undermined three of the arches, they were carried away, and were not rebuilt again until 1746. At Willington and others of the mills in the upper parts of this navigation, there is a kind of self-acting sluices in use, which fall down to let the water pass freely over them, when the water in a flood rises above a certain height; the locks on this part of the navigation are of wood, the towing-path has stiles near it, and is frequently interrupted as before mentioned. In November 1796 a dry dock in Lynn, connecting with this river, was opened, being the first work of the kind which had been erected for the accommodation of that port. About the year 1780, a cut, of about 1½ mile in length, was made from this river, in Willington, to the turnpike road in Cople, where a house and conveniencies for a wharf were built (now the Dog ale-house) at a great expence; but the consent of the proprietor of the *Ouse* navigation, who holds it under a particular grant from the crown, could not afterwards be obtained for this cut being used as a navigation. In 1785, and again in 1802, the *London Lynn and Norwich* canal was proposed to join this river at Lynn. And in 1792, the *Leicester and London* was proposed to join and cross it at Bedford.

Ouse (*Little*) River. This river (often called the Brandon) has its course nearly east, for about 20 miles, between the counties of Norfolk and Suffolk: it is not greatly elevated in any part: its objects are the import of coals, deals, and the export of agricultural products. Brandon and Thetford are considerable towns on this river, which commences in the great *Ouse*, at Rebeck, and terminates at the town of Thetford, to which place boats with 14 or 15 chaldrons of coals in each could come up in the year 1649. The lower part of this river for several miles is embanked on both sides, through the fens. In the year 1789, this navigation was proposed to be joined at Hiss near Wilton by the intended *Bishopstortford and Wilton* canal.

Ouse River (*York*). Act 23 Henry VIII.—The general direction of this river is nearly north-west for about 48 miles, between the East, West, and North Ridings and Ainsty Liberty in Yorkshire; it is not very greatly elevated in any part; its objects are the trade and supply of the city of York, and of the immensely populous and trading districts in the West Riding. At Goole Bridge it is joined by the *Don* river; at Armyn, by the *Ayre and Calder* navigation; at Barnby, by the *Derwent* river; at Selby, by a cut of the *Ayre and Calder* navigation; near Cawood, by the *Wharfe* river; and at York, by the *Foss* river. York is the 23d British town, with a population of 16,145 persons. Howden, Snaith, Selby, and Cawood are also considerable places on or near this river; which commences in the *Humber* river at Trent-fall (the junction of the *Trent* river) to the *Yore* river at Linton. Ships of 150 or 160 tons burthen come up to Armyn, and smaller masted vessels to York city. By a licence of Richard II. the corporation of York are required to maintain certain bridges on the upper part of this river. In the year 1795, a large wooden draw-bridge, of 13 openings, was built by Mr. *William Jessop* over this river at Selby, under an act of parliament. In 1769, the *Selby and Leeds* canal was proposed to connect with this river at Selby.

Oxford Canal. Acts 9, 15, 26, 34, and 39 of Geo. III.—The general direction of this canal is nearly north, by a very crooked course in its northern half, of 91 miles, in the counties of Oxford, Warwick, and Northampton; it crosses the grand-ridge by a tunnel, and its northern part skirts along near to it on the western side for many miles; its objects were a communication between the midland canals and the metropolis, (but a much nearer route is now opened by the *Grand-Junction* canal,) the supply of the northern parts of Oxfordshire with coals, the export of farming products, &c. At Woolvercot is a cut of about ¼ mile (belonging to the duke of Marlborough), by which a communication with the *Thames and Isis* navigation at Godstow is effected. At Napton the *Warwick and Napton* canal joins this; and at Braunston the *Grand-Junction* canal joins. Coventry is the 24th British town, with a population of 16,034 persons; and Oxford is the 38th, with 11,694 persons. Woodstock, Deddington, Banbury, Southam, Daventry, and Rugby are also considerable towns on or near to this line of canal; which commences in the *Thames and Isis* navigation at Badcock's Garden on the west side of Oxford city, and terminates in the *Coventry* canal at Longford. At Hillmorton and at Napton are short cuts, of about ½ a mile each, to the steam-engines belonging to this company. From the *Thames and Isis* at Oxford to Banbury, 27¼ miles, is a rise of 118 feet by 18 locks (including 2 weir-locks and an entrance lock from the Isis); thence to Claydon, 7¼ miles, is a rise of 77½ feet by 12 locks; thence (through the Fenny-Compton tunnel) the summit pound continues to Marston-doles wharf 10¾ miles, and level; thence to Napton on the hill 2 miles, is a fall of 55¼ feet by 9 locks; thence to Hillmorton, 16¾ miles (in which the *Warwick and Napton* and the *Grand-Junction* join), is level; thence in ½ a mile is a fall of 19 feet by 3 locks; thence to the *Coventry* canal at Longford, 26½ miles, is level. The two short cuts to the engines, and that at Woolvercot, are level. This canal is 28 feet wide at top, 16 feet at bottom, and 4½ feet deep, except the summit pound, which is made 6 feet deep in order to act as a reservoir; the locks are 74¾ feet long, and 7 feet wide. At the toll-house near Longford is a stop-lock, to prevent the *Coventry* canal in dry seasons, from lowering the water in the long pound on this; from which long pound an engine at Hillmorton pumps water into the Braunston pound, by means of a feeder; and out of this last pound by means of a lough. Another engine at Napton pumps into the summit pound, which is also fed by three reservoirs. The number of stone and brick bridges on this line is 188, and of wooden, swing, draw, and foot bridges 66. The Fenny-Compton tunnel is 1188 yards long, 9½ feet wide, and 15½ feet high. At Newbold is a tunnel 125 yards long, made under the church-yard and street, 16 feet high, and 12½ feet wide, with a towing-path through it. At Wolfhamcote, also, there is a short tunnel. At Pedlars-Bridge near Brinklow is an aqueduct bridge of 12 arches, of 22 feet span each. At Cosford on the Swift river, and at Clifton on the Avon, are others of 2 arches each; at Wolfhamcote, Adderbury, and Hampton-Gay, are other smaller aqueducts. Mr. *James Brindley* made the survey for this canal in September 1768; in August 1769 he began the work near Longford; and in 1775 it was completed from thence to the Napton locks; when 122,300l. having been expended, the works stood still for want of money until 5th April 1786, when they were resumed; on the 31st of March 1778 the line was opened northward to Banbury; and on the 1st of January 1790 the whole was completed. Mr. *James Barnes* was employed to execute some of the digging of this part. This company have been

authorised to raise, by their different acts, 330,000l.; the amount of their shares is 100l. each. In January 1800 these are said to have sold for 194l., and in 1802 for 275l. each; the *Grand-Junction* company being bound to make up the tolls hereon to 10,000l. annually, (if the works are kept in order) on condition of this company taking only certain tolls on goods passing to or from that canal, (see *Phillips*'s 4to. *Hist. Apend.* p. 32.) and agreeing to widen about 35 miles of their canal and locks, that large boats may pass north of Braunston, whenever the *Grand-Junction* company shall require the same of this and the *Coventry* company. The rates of tonnage are rather complicated; they will be found in *Cary's Inland Navigation*, pages 59, 74, and 80. For parcels under 5 cwt. the company are to fix specific rates in their printed tonnage tables. Coals from the inland pits were not allowed, by the first act above, to come nearer to London than Oxford; but by the 3d act, this was extended to Reading and the *Kennet* navigation; and in the year 1800 this company offered 2s. per ton as a premium on coals carried certain distances from their canal into Berkshire, &c. The narrow barges used on this canal seldom venture down the *Thames* to London, but goods are generally shifted at Oxford into the Thames-barges. About the year 1792 the *Stratford and Cropredy* canal was proposed to join this at Cropredy; and, at the same time, a canal from *Hampton-Gay to Isleworth* was intended, to join this at Hampton-Gay.

Parnel's Canal. This short canal, or rather water-level, has nearly a north direction for about ½ a mile in the valley north of St. Austle, (near the south coast of Cornwall) one mile above that town; it commences within an immense excavation of great depth, and open to day, which has, by the work of ages, been made in a rocky hill abounding with tin ore. It is tunnelled through the solid rock for 200 yards or more, on a level to the surface of the hill, and proceeds forwards thereon to the top of an inclined plane, of about 50 feet fall, where the boats are raised up an end by a windlass to shoot out the ore, as already described on *St. Columb* canal. At the bottom of the plane the ore is loaded into carts, to be carted to the stamping-mills. Small square-headed boats are used, and four or five of them are linked together to be shoved through the tunnel, by means of chains which are fixed along its sides for that purpose, and they are afterwards towed along the canal to the head of the plane. This canal, tunnel, and plane, were made at the expence of Mr. *Parnel*, who owns the mine, about the year 1770, before which the ore was drawn up to the top edge of the pit or mine, and carted from thence.

Parret River. The course of this river is nearly south-east for about 5 miles, in the county of Somerset; it is not greatly elevated; its objects are the import of coals, and the export of agricultural products. Langport is the only considerable town near this navigation. It commences in the *Tone and Parret* navigation at Borough-Chapel, and terminates in the *Ivelchester and Langport* navigation, a little below Langport.

Peak-Forest Canal. Acts 34, 40, and 45 of Geo. III. —The general direction of this canal and rail-way is nearly south-east for 21 miles, in the counties of Chester and Derby; its southern end is very considerably elevated, and terminates on, or very near to, the Grand-Ridge; its principal object is the export of the Peak-Forest lime, and of coals from the neighbourhood of this canal. Ashton-under-line, Stockport, and Chapel-le-Frith are considerable towns on or near this line; which commences in the *Manchester Ashton and Oldham* canal, at Duckenfield, (near to the termination of the *Huddersfield* canal,) and the canal terminates at the bason and lime-kilns in Chapel-Milton, whence a rail-way proceeds to Loads-knowl lime-stone quarries in the Peak. The line of the canal is 15 miles in length, and of the rail-way 6 miles; there is a cut of ½ a mile to Whaley-Bridge, and a rail-way branch of 1½ mile to Marple. Over the Mersey river, near Marple, is a grand aqueduct bridge of 3 arches, each 60 feet span and 78 feet high, the whole height of the structure being near 100 feet, which was built in the year 1799. (This bridge we have before, by mistake, when treating of Aqueducts, mentioned as being on the *Manchester Ashton and Oldham* canal.) Mr. *Benjamin Outram* was the engineer, and the works were completed on the 1st of May 1800. The company were authorised to raise, by the first act, 150,000l., each share being 100l., which in 1802 bore a premium of 10 per cent. It has been said, on several occasions, that this canal and rail-way were completed at 10 per cent. under the original estimate, and that the 2d act authorised the company to raise any unlimited sum that they might want, in which there certainly were mistakes, because the act of the last sessions was for raising a further sum of money. For the rates of tonnage and wharfage, see *Phillips*'s 4to. *History, App.* p. 155. Mine-waters may be used for the supply of this canal, but only the flood-waters of the rivers.

Pentland Firth. This streight has nearly a west direction between Caithness county, at the north-eastern extremity of Scotland, and the Orkney islands. This, though a rocky and dangerous passage, is much frequented by ships, on account of being the first passage which presents itself for ships in going northward, between the East and West Seas, or German Ocean and Irish Sea. The *Inverness and Fort-William* canal, now cutting a great way south of this for the use of ships, is expected much to lessen the use of this firth. Serabster road-stead, on the side of this firth, is a harbour much frequented by ships in blowing weather. Thurso harbour in Caithness, on the southern side of this firth, has a pier now building, and its harbour improving, under an act of 42 of Geo. III.

Polbrock Canal. Act 37 of Geo. III.—The general direction of this canal is nearly south-east for about 5 miles in Cornwall, near its north-west coast; it is not greatly elevated; its objects are the import of coals, and the export of stone and agricultural products. Bodmin is a considerable town near it. It commences at Guinea-port, near Wadebridge, in the *Camel* river, and terminates at Dunmeer Bridge and Stoney Lane, in the parish of Bodmin, having a collateral cut of ½ a mile to Ruther Bridge, in the same parish. At Guinea port and at Stoney-Lane Bridge large and convenient basons and warehouses are intended. Mr. *John Rennie* and Mr. *Murray* are the engineers. This company may raise 18,000l. in 50l. shares. A feeder from the Camel river and any springs within 2000 yards may also be taken for this canal.

Poole Harbour. This spacious inlet or harbour has nearly a west course for about 9 miles, in the county of Dorset; the tide flows into every part of its various branches and inlets, and round Branksea island, which is in the middle of it; its object, besides the general trade and supply of the neighbourhood, is the export of a fine potter's clay found near to Corfe Castle, in the isle of Purbeck, and paving-stones and free-stone from thence. Poole, Wareham, and Corfe Castle are considerable towns near this harbour, which commences in Studland Bay and terminates at Wareham Bridge: a branch proceeds about 2¼ miles north to Creek-Moor. In 1797 several improvements in this harbour were in contemplation.

Portsmouth Harbour. This inlet or harbour has

nearly a north courſe, for about $5\frac{1}{2}$ miles, in Hampſhire; the tide flows through it, and the depth of water in moſt parts of it is ſufficient for the large ſhips of the Britiſh navy. Portſmouth is the 13th Britiſh town, with a population of 32,166 perſons; Goſport and Fareham are alſo conſiderable towns adjoining it. It commences at Spithead, in the Channel, between Hampſhire and the Iſle of Wight, and terminates at Fareham Bridge, having alſo a branch to Coſham, and a communication therefrom to Langſtone and Chicheſter harbours. On the ſhores of this harbour there are immenſe buildings and works, for the uſe and ſecurity of the royal navy. In 1805 ſeveral conſiderable additions were making to theſe works, and a bridge between Goſport and Haſlar hoſpital, which Mr. Robert Forbes built ſome years ago, is intended to be taken down, having proved injurious to the harbour.

Portſmouth and Croydon Canal. In the years 1802 and 1803, a canal was in contemplation from *Portſmouth Harbour* to the *Croydon Canal* at that town, paſſing Havant, Chicheſter, Arundel, Horſham, Ryegate, and Merſtham, of which that able engineer, Mr. *John Rennie*, prepared plans and an eſtimate; but the oppoſition of the land-owners, and favourers of a rail-way ſcheme from *Portſmouth to London* procured its rejection in parliament. The ſummit-level of this canal was to be 36 miles in length, at about 220 feet above the level of the ſea: this was to be fed by ſeveral reſervoirs in or near Horſham Foreſt, containing in the whole 500 acres, and 340,000.000 cubic feet of water. This level was to penetrate the Chalk-Hills north eaſt of Merſtham, by a tunnel $4\frac{1}{4}$ miles long, and 350 feet below the top of thoſe hills. The eſtimated expence was 721,000l., and 800,000l. in 100l. ſhares was propoſed to be raiſed; the expected revenue was eſtimated at 100 000l. per annum. While this line was in contemplation, there was an attempt made by Mr. *Ralph Dodd* to draw the public attention to a different line of canal, (which Mr. *John Phillips* laid claim to, as being one of the fanciful ones which he has drawn in the map to his 4to. Hiſtory, 1791.) from *Portſmouth Harbour*, through *Southampton Water* and the *Itchen River*, to Wincheſter; thence to Alresford, near to Alton and Farnham, and to the Wey river at Godalming: from near Weſtley on that river, the propoſed line of the *Grand Surrey* canal was to be followed to Deptford and the *Thames* river. The eſtimate mentioned on this occaſion was 348,735l.

Portſmouth and London Rail-way. In 1803, Mr. *William Jeſſop* was employed to ſurvey the line of a rail-way from Portſmouth town to the weſt end of Stamford-Street, near Blackfriars-Bridge, London; on the utility of which, and the *Portſmouth and Croydon* canal above, opinions were for ſome time divided: in the end, neither of them was adopted. The eſtimated expence of this work was 400.000l.

Ramsden's Canal. Act 14 Geo. III.—The general direction of this canal is nearly ſouth-weſt for about 8 miles, in the Weſt Riding of Yorkſhire; it is not very greatly elevated; its objects at firſt were the ſupply and trade of Huddersfield town, but it will ſhortly have conſiderable importance as part of the ſhorteſt line of navigation between Hull and Mancheſter and Liverpool. Huddersfield is the 81ſt Britiſh town, with a population of 7268 perſons. This canal commences in the *Calder and Hebble* navigation, at Cooper's Bridge, and terminates in the *Huddersfield* canal, at King's Mill near Huddersfield; it has a riſe of $56\frac{3}{4}$ feet by 9 locks. Sir *John Ramſden*, who is the ſole proprietor of this canal and of Huddersfield town, in 1766 employed Mr. *James Brindley* to plan this canal; and, after his death, it was begun and quickly completed by Mr. *Luke Holt*. At Huddersfield ſpacious warehouſes are built by the ſide of this canal, to which goods intended to be there lodged may be carried toll-free along the part of this canal from the *Huddersfield* canal; that company guaranteeing the tolls on this not to be leſſened thereby. On the whole length or any part of this canal, coals, flags, ſlates, ſtones, lime ſtones, and lime, are to pay a toll of 3d. per ton, and all other goods 1s. 6d. per ton, except dung and manures, which are to paſs free. The proprietors' profits are never to exceed 6 per cent. upon the monies laid out thereon.

Reading and Maidenhead. In 1770, a canal was propoſed from the *Thames* river, at Bolter's Lock near Taplow-Hill, (at the weſtern termination of the *Maidenhead and Iſleworth* propoſed canal,) to the *Thames* again, at Sunning near Reading and to the *Kennet* river, on which Mr. *James Brindley* was conſulted by the city of London, the diſtance being near 15 miles by the canal, and by the river above 30 miles, between the ſame places; a barge of 120 tons being 3 days (and often in dry times as many weeks) in performing the voyage, at an expence equal to 50l.; while, by this canal, it was calculated that a barge might at all times, except froſt, perform it in 6 hours, at 4l. 7s. expence, including $\frac{1}{2}$d. per ton to the truſtees as a toll. This canal was at firſt propoſed to commence at Monkey iſland in the *Thames*, which is 2 miles below Maidenhead-Bridge. No private property was to be allowed in this canal, but the money was propoſed to be raiſed by life annuities, out of which, and the tolls, the river navigation was to be improved between Bolter's Lock and Sunning, without any new tolls being charged thereon; and when a ſufficient fund was accumulated for repairs and management, the tolls were to ceaſe, and the canal be entirely free.

Ribble River. The direction of this river is nearly eaſt for about 12 miles in the county of Lancaſter; the tide flows through its whole length: its objects are the ſupply and trade of Preſton town, and the export of coals brought down by the *Douglas* river, which joins it near Haſketh. Preſton is the 37th Britiſh town, with a population of 11,887 perſons. This river commences with a very wide eſtuary or mouth in the Iriſh Sea, but grows very ſhallow, ſo as to be fordable at low-water, and terminates at the bridge at Preſton, near to the aqueduct bridge, on which the *Lancaſter* canal croſſes this river. In September laſt, (1805) it was propoſed to apply for an act for placing buoys, and otherwiſe improving the navigation of this river.

Ripon Canal. Act 7 Geo. III.—The general direction of this canal is nearly N.W. by a bending courſe of about 7 miles in the Weſt, and ſkirting the North Riding of Yorkſhire: its objects are the ſupply of Ripon, and the export of agricultural products, ſtone, &c. It is conſiderably elevated; Borough-bridge, Ripon, and Aldborough, are conſiderable towns on or near this canal, which commences in the *Yore* river at Milby, near Borough-bridge, and terminates at Ripon.

Rochdale Canal. Acts 34, 40, and 44 of Geo. III.—The general direction of this canal is nearly N. E. by a bending courſe of $31\frac{1}{2}$ miles in the counties of Lancaſter and York; it croſſes the grand-ridge by a deep-cutting: its general objects are the communication between Liverpool and Mancheſter, with Halifax, Wakefield, Hull, &c. the export of coals, paving-ſtones, &c. At Piccadilly ſtreet in Mancheſter it is joined by the *Mancheſter Aſhton and Oldham* canal. Mancheſter is the 2d Britiſh town, with a population of 84,020 perſons; Huddersfield is the 44th, with 10,671 perſons; Spotland the 55th, with 9,031 perſons; and Halifax the 58th, with 8,886 perſons. This canal commences in *Bridgewater*'s canal at Caſtle-Field in Mancheſ-

ter, and terminates in the *Calder and Hebble* navigation at the bason, wharf and warehouses at Sowerby bridge: to near Hollingwood chapel there is a branch of ¾ of a mile, and another of ½ a mile to School-lane in Castleton near Rochdale. From *Bridgewater's* canal to Piccadilly wharf, and the *Manchester Ashton and Oldham* canal, 1¼ mile, has a rise of 75½ feet; thence to the Hollingwood branch, 4¾ miles, has a rise of 81 feet; thence to Failsworth brook, 2¼ miles, is level; thence to the Rochdale branch, 4¾ miles, has a rise of 120 feet; thence to Clay-hall, 2¼ miles, has a rise of 62 feet; thence along the summit-pound and through the deep-cutting to Travis-mill, 5⅝, is level; thence to the *Calder and Hebble* navigation, 11⅞ miles, has a fall of 275 feet; the Hollingwood and Rochdale branches are level. From near Rochdale to Sowerby-Bridge there are 49 locks, (which are of the same width and length as *Bridgewater's* at Runcorn:) more than 60 bridges and 8 aqueducts and large culverts. At Hallin's mill is a tunnel of 70 yards in length, 17 feet high and 21 feet wide, with a towing-path through it. At Dean-Head, between Littleborough and Todmerden, is a stupendous deep-cutting in hard rock, some of it 50 feet deep. A very large reservoir is made on the west side of the summit, and an 100 horse steam-engine is used to pump the water up to the summit-pound. On a bog on Blackstone edge are two other large reservoirs, one of them 14 yards deep. Gauges for regulating the streams of the Roch, Irwell and Irk rivers, so that only their surplus flood-waters are taken for the supply of this canal, were contrived and erected by Mr. *John Rennie*, the engineer. Steam-engines within 20 yards of the canal are allowed to condense by its water. On the 28th of December 1798, the east end of the line from Sowerby bridge to Rochdale was completed; on 18th September 1802, it was continued to Lomeside wharf; and on 21st December 1804, the whole line was completed and opened to Manchester. This company are to pay a compensation to the duke of *Bridgewater* for his warehouses at Castle-Field, and to the *Calder and Hebble* company for their warehouses at Sowerby bridge. This company were authorised by their first act to raise 391,000l. (the amount of shares 100l. each) and by the last act they were authorised to raise a large sum in addition. The rates of tonnage and wharfage, and the exemptions in the first act, will be found in *Phillips's* 4to. *History*, pages 157 and 159, to 161; also, by the second act, certain additions were made to these tolls. Cuts or rails-ways may be made to any present or future coal-mines near the line. In 1791 a branch from this canal was proposed from near Todmarden (104 feet below the summit-level) to 2 miles beyond Colne, having a tunnel thereon of 1½ mile in length, about 3 miles N. E. of Todmarden.

Rother River. The general direction of this river is nearly N.W. by a crooked course of about 19 miles in the counties of Sussex and Kent; it is but little elevated above the sea in any part: its objects are the import of coals, &c. and the export of oak-timber and agricultural products: near Rye harbour, opposite to Pleydon-heights, it is joined by the *Shorncliff and Rye* canal. Rye, Winchelsea, Appledore, and Tenterden are considerable towns on or near to this navigation; which commences in the tide-way of the English Channel near Rye old harbour, and terminates at Roberts-bridge; it has a branch of about 2½ miles to Winchelsea bridge, and some other navigable branches in the level fens which surround Oxney Island, and adjoin Romney-marsh. The harbour of Rye near the mouth of this river, from its tendency to choak up, formerly employed the abilities of captain *John Perry*, Mr. *John Smeaton*, and other eminent engineers; and under the acts of 29 Geo. I. and 1, 37, and 41 of Geo. III. several works have been constructed. Previous to the reign of Edward I., it is said, that the *Rother* vented its waters into the sea at old Romney harbour, about which time a new channel was cut for it to sea at old Rye-harbour, which for a long time scoured itself out, and was deep enough for the use of large vessels, the tide flowing 24 miles up the river; but sea-sluices being afterwards erected in improper situations, and embankments made, by which (before 1698) the channel became too shallow for ships, and in 1719 it was rendered quite useless for navigation; soon after 1721, the sluices above mentioned were removed, but the evil was become so irreparable, that captain *Perry* advised, and effected the cutting of, an entire new channel of about a mile in length, 150 feet wide at top, and 70 at bottom, since called the new harbour (from the sea, near 2 miles west of the old harbour) into the channel of the Winchelsea river, and through that to the *Rother* and old harbour at Rye; this new canal (finished 14th July 1762) had about its middle part, a stone sluice of two openings, one for the passage of vessels, and the tide near high-water, 40 feet wide, shut by double gates pointing to Landward, and another of 30 feet wide, closed by 5 draw-gates, to be occasionally opened for scowering the mouth of the new channel or harbour, at which there were two stone piers erected at 120 feet apart. The upland and tide waters continued to have their course to sea by the old channel or harbour, and Mr. *Smeaton* who was consulted in 1763, confidently foretold, that unless the old channel was closed up near Rye, below the entrance to the new one, so as to turn the upland waters through the new harbour, it would be in time quite filted up, as happened so completely previous to 1797, that an act then passed repealing all the former acts relating to this new harbour, and the tonnage which coasting vessels had paid since it was established, on passing or entering the same, was transferred to Ramsgate harbour, near *Stour* river, into which such ships are able to run for shelter, in case of a storm coming on. The new Rye-harbour was in consequence blocked up, by a bank below the Winchelsea river, over which the new road between Winchelsea and Rye now passes: soon after this, the *Rev. Daniel Pope* revived the ideas of Messrs. *Perry* and *Smeaton*, with regard to the entrance of the old harbour, and by the assistance of Mr. *Southerden*, cut a new channel, or sea vent, for the river, about ¾ of a mile west of the old harbour's mouth, and being about ¾ of a mile in length, before it intersected the old harbour: at this place Mr. *Pope* constructed a dam of straw, faggots, and gravel, which effectually blocked up the old harbour's entrance, and forced the tide to enter and return, and the river waters to vent themselves through his new cut (as Mr. *Smeaton* had in vain before recommended to be done with Mr. *Perry's* new cut.) After which, Mr. *Sutherland* constructed a pier-head on the east side, and two jetties on the west side of the present entrance to the harbour, which is now said (see *Transactions of the Society of Arts*, vol. xxii. p. 249) to be capable of admitting ships of 250 and 300 tons burthen at spring tides, which here rise 23 feet, and the neap tides 14 feet. In December 1799, it was proposed to improve the navigation of this river between Rye and Robertsbridge, to extend the navigation of the Winchelsea branch to Siddlescombe, and to make a new navigable branch from Blackwall to Smallhithe near Tenterden. In April 1802, this last branch was proposed to be joined by the intended *Medway and Rother* canal.

Sandbach Canal. In the year 1793, a canal was proposed to be made from the *Severn* river below Shrewsbury to the *Trent and Mersey* canal at Sandbach, with a cut to Betley, and another to join the *Chester* canal near Nantwich. The *Ternbridge and Winsford*, and the *Newport and Stone* canals,

have at different times been propofed through parts of the fame tract of country.

Sankey Canal. Acts 28 of Geo. II. and 1 of Geo. III. —The general direction of this canal is nearly N.W. by fo very bending a courfe, that it exceeds a femicircle; its length is 12¼ miles in the county of Lancafter; it is not very greatly elevated in any part: its objects are the export of coals and flates, and the fupply and trade of St. Hellens and Newton, and the copper, glafs, and other works near them; near Sankey bridge it connects with, and is croffed by the fide-cut made in 1804 for avoiding the fhallows in the *Merfey* between Warrington and Runcorn. Warrington is the 45th Britifh town, with a population of 10,567 perfons; Newton and St. Hellens are alfo confiderable towns near, or on this canal; which commences in the *Merfey and Irwell* navigation at Fiddlers-ferry, and terminates near Sutton-heath collieries. Near the mouth of Sankey brook it has a fhort cut of about ⅛ of a mile, forming another communication with the *Merfey* river; there is a branch of about ⅜ of a mile to Penny bridge, and another of ¼ of a mile to Gerrard's bridge. From the *Merfey* to Sutton heath is a rife of 78 feet, by 8 fix-feet locks, and 2 double locks of 15 feet rife each. The higheft fpring tides rife within about a foot of the level of the water at the firft lock. Veffels deeply laden were generally unable to pafs into or out of the *Merfey* for two or three days of neap tides before the *Merfey* cut above mentioned was made. This canal is 48 feet wide and $5\frac{7}{12}$ feet deep in water; it has 18 bridges, all of which are wooden fwing-bridges, even for the great turnpike road between Manchefter and Liverpool. Between St. Hellens and Sutton-heath there is a fhort tunnel; the canal is fed by a feeder from Sankey brook, and there are provifions for enabling the farmers near this canal to irrigate therefrom, between the 10th of October and 1ft of May annually. Mr. *John Eyes* was the engineer, and has the honour of completing this, *the firft Englifh canal*, that was attempted; it was opened between the *Merfey* and Gerrard's bridge in the year 1760. The fum of money to be raifed for the purpofes of this canal is not limited in the acts, as is done in all modern canal acts. The proprietors are authorifed to take 12d. per ton on all goods which are navigated on any part of their canal, except limeftone, road-materials and manures, which are toll free: 63 cubical feet of coal, cannel, charcoal, coke, or cinders, are to be rated as a ton, and a bufhel of coals is to be heaped meafure in a veffel 19½ inches diameter outfide, and capable of containing one bufhel and one quart of water Winchefter meafure. In June 1797, a loaded barge was rowed 20 miles on this canal by a machine worked by a fteam-engine on board of the barge, as before mentioned.

Selby and Leeds. In 1769, Mr. *James Brindley* furveyed the line of a canal from the *Oufe* river at Selby to the *Leeds and Liverpool* canal (near to the termination of the *Ayre and Calder* navigation) at Leeds: it was propofed to pafs Thorp dam, near to Thorp hall, Hambleton, Hillham, Burton-Salmon, (where a tunnel was intended,) near Fairburn, Newton, the Fire engines, and crofs the Ayre river, by Thwait mill, Hunflet, and fo on to Leeds, a courfe of 23 miles in length: the oppofition of the *Ayre and Calder* company, who were in the reign of William III. indulged with very high rates of tonnage, and fome other perfons, proved fatal to this fcheme when it came before parliament.

Severn River. Acts 19 Hen. VII., 23 Hen. VIII. and 12 and 43 of Geo. III.—The general direction of this noble river is nearly north, by a crooked and bending courfe of about 174 miles, fkirting the counties of Somerfet, Gloucefter, Glamorgan, Monmouth, and Hereford, and through the counties of Worcefter, Salop, and Montgommery; commencing in the tide-way in the *Briftol Channel*, at Flat-Holm light-houfe, and terminating in the *Montgommery* canal at Welfhpool. Its northern end is confiderably elevated: the trade of various kinds is very immenfe on this important river, and the many navigations which connect therewith. At the lower layer it is joined by the *Glamorganfhire* canal and *Cardiff and Merthyr-Tydvill* rail-way; at New Amfterdam by the *Sirhowy* rail way; at Nafh by the *Ufke* river; (not far from its junction with *Monmouthfhire* canal, and a branch of *Sirhowy* rail-way); at King's Road by the Bath *Avon* river; at Beachley by the *Wye* river; at Berkley-Pill, Hotch-Crib, and at Gloucefter by the *Gloucefter and Berkley* canal; at Framiload by the *Stroudwater* river and canal; at Gloucefter, on each fide of Alney Ifle, and at Laffington by the *Hereford and Gloucefter*; at Fletcher's leap with *Coombe-hill* canal; at Tewkfbury by the Stratford *Avon*; at Diglis by the *Worcefter and Birmingham*; at Hawford by the *Droitwich* canal: at Stourport by the *Stour* river and *Staffordfhire and Worcefterfhire*, and the *Leominfter* canals; at Coal-port and at Loads-croft near Coalbrooke dale, by the *Shropfhire* canal; and at Shrewfbury by the *Shrewfbury* and *Ellefmere* canals. Briftol is the 7th Britifh town, with a population of 68,645 perfons; Shrewfbury the 36th, with 14,739 perfons; Worcefter the 40th, with 11,352 perfons; and Gloucefter the 72d, with 7,579 perfons; Cardiff, Newport, Chepftow, Thornbury, Berkley, Newnham, Tewkfbury, Upton, Bewdley, Kidderminfter, Bridge-North, Much-Wenlock and Welfhpool, are alfo confiderable towns near to, or upon this river. The falls which this river has in particular parts have been mentioned in a preceding part of this article, as alfo a valuable experiment of 11 years continuance on the floods, droughts, and frofts which affected its navigation; which is unaffifted by any locks, fide-cuts, weirs, or other erections, except the towing-paths, which Mr. *William Reynolds* begun between Coal port and Coalbrook-dale, in confequence of an act, 12 of Geo. III., fince renewed, for making a towing-path between Coalbrook-dale and Bewdley bridge, and levying certain tolls on goods navigated on that part of the river for defraying the expences of fuch path, which has been fince completed; and in 43 of Geo. III. a fimilar act for making a towing-path from Bewdley bridge to the *Worcefter and Birmingham* canal at Diglis below Worcefter, which is, we believe, alfo completed. The trade on the middle parts of this river is carried on by two forts of veffels, viz. barges 40 to 60 feet long with a fingle maft and fquare fail, carrying from 20 to 40 tons, and trows with a main and top-maft about 80 feet high, and fquare fails; thefe are 160 feet long and 16 to 20 feet in width, and carry 40 to 80 tons. Some years ago, Mr. *John Wilkinfon* introduced fome barges made of caft iron plates for navigating this river. In the 16 Geo. III. an act was obtained for erecting a caft-iron bridge of one arch (the firft ever erected; fee our article Bridge) over this river at Brofely or Madeley wood near Coalbrook-dale. The high floods, in 1795, carried away a narrow and inconvenient ftone bridge that was at Buildwas, about 2 miles above Madeley wood, and in 1796, a new caft-iron bridge was erected in its ftead, as before defcribed: by an act of the 17 Geo. III. a new ftone bridge was erected over this river at Gloucefter, by which the navigation there was much improved. At Shrewfbury the very long and curving loop of the river is tunnelled through by a fmall arch for conveying water to feveral mills at its junction again with the river. In the year 1765, the *Ternbridge and Windsford* canal was propofed to join this river at Ternbridge; in 1786 the *Stourbridge and Worcefter* was propofed to join at Diglis; in 1793, the *Sandbach*, and

another canal in opposition to the *Ellesmere* (called, in some maps, the Eastern Grand Trunk,) were proposed to join this river below Shrewsbury. In 1795, the *Welshpool and Leominster* was intended to join at Welshpool; in 1797, the *Bristol and Gloucester* was proposed to join, both at Gloucester and at Worcester, to this river; and, in 1801, the *Severn and Wye* rail-way was proposed to join this river at Lidney.

Severn and Wye Rail-way. In the year 1801, a line of rail-way was projected from the *Severn* river at Lidney, across the forest of Dean, connecting with the collieries thereon, and extending to the *Wye* river at English Bichnor, we believe. At a meeting, on the 14th of June, 1802, the southern part of this design was relinquished, and the *Dean-Forest* rail-way was proposed in lieu of the other part.

Shannon River, (*Ireland*). The general direction of this famous river is nearly N.E. by a crooked course of more than 100 miles, between the counties of Kerry, Limerick, Clare, Tipperary, Galway, King's county, Meath, Longford, Elphin, and Leitrim in Ireland. It commences in the Atlantic Ocean, at Loop-head, and terminates at Carrick on the Shannon, which is 65 miles above Banagher. It is joined by the *Grand Canal* at Tormanbury, and it also is joined by the *Limerick* canal. Limerick, Kilalow, Clonfort, Leitrim, Carr, Longford, Roscommon, Athlone, Portumny, Nenagh, Askeaton, Clare-Abbey, &c. are considerable towns on or near to this river. About the year 1750, the improvement of the navigation on this river was attempted, by the erection of sluices with gates on its stream, for damming up and making flashes for the boats to pass through with. The Irish parliament, at different periods, between 1753 and 1771, granted several sums of the public money, amounting to 39,160l. for the improvement of this navigation. It was not until about March 1804, that the upper part of the navigation on this river was completed.

Shorncliff and Rye Canal. Defence act 43 Geo. III.—The general direction of this singular canal is nearly S.W. by a bending course of about 18 miles, through Romney marsh in the counties of Kent and Sussex. It is so nearly level with the sea as to require no locks but the tide-locks at its extremities. Its objects, besides aiding the defence of this part of our coast, is the import of coals and sea-beach for road-making; the export of farming products, and improving the drainage of the marsh: Hythe, Rye, Appledore, and Folkstone are considerable towns near this line; which commences in the tide-way of the English channel at Shorncliff battery near Hythe, and terminates in the tide-way of the *Rother* river opposite Pleydon Heights near Rye. This canal is of width and depth sufficient for vessels of 200 tons to navigate; it has a military road by its side, and is flanked throughout with batteries of great strength. This canal was projected by the royal military engineers, in the autumn of 1804; and in June last (1805) 3000 men were said to be employed thereon, and before now it is, we believe, completed.

Shrewsbury Canal. Act 33 Geo. III.—The general direction of this canal is nearly E. by a crooked course of $17\frac{1}{2}$ miles in length, in the county of Salop: its eastern end is greatly elevated, and at no great distance from the grand-ridge on its western side; its objects are the export of coals from its eastern end, for the supply of Shrewsbury, and supplying the same with farming products, and the country with lime and manures; at Wombridge it is joined by the *Ketley* canal. Shrewsbury is the 36th British town, with 14,739 persons. This canal commences in Castle Foregate bason, at the town of Shrewsbury, (near to the *Ellesmere* canal, with which it may be joined by mutual consent,) and terminates in the *Shropshire* canal above Wrockandire-wood plane near Oaken-gates. From Shrewsbury to Langdon, near 12 miles, is level; thence to near Wombridge, $4\frac{1}{4}$ miles, is a rise of 79 feet, by locks; thence is an inclined plane of 75 feet rise, and near $\frac{1}{4}$ of a mile in length, to the *Ketley* canal; thence (along the part which was purchased by this company of Mr. *William Reynolds* for 840l. being half of what it cost) to the *Shropshire* canal, $1\frac{1}{4}$ mile, is level. The locks on this canal are contrived in two divisions by doors, which draw up, out of a recess formed for them below the locks, so that a long narrow canal boat of the usual construction, or two or four smaller and narrow flat-bottomed boats adapted to the inclined-plane, can pass the same without unnecessary waste of water. Near Atcham is a tunnel of 970 yards in length, and 10 feet wide, which has a towing-path 3 feet wide through it, constructed of wood, and supported on bearers from the wall, so as not to diminish the water-way. At Long is a long embankment and an aqueduct bridge, or rather trough of cast iron, over the Tern river, 62 yards long, and 16 feet above the level meadows, of which we have already given a description in this article; at Roddington are another embankment and a common aqueduct bridge, 21 feet above the surface of the Roden river, over which the canal passes, and at Pimley there are another embankment and aqueduct of less height and width than the former ones. At Wombridge there is a double *inclined-plane* of 223 yards in length, and 75 feet perpendicular rise, up one of which, empty or partly laden boats are drawn by the aid of a steam-engine, or by the descent of a loaded boat at the same time on the other, as we have before described. Mr. *Thomas Telford* and Mr. *William Reynolds* were the engineers employed or consulted on the construction of the works on this canal. In March 1796, the Long aqueduct was finished; and in February 1797, the whole line was completed and opened. This company was authorised to raise 70,000l. the amount of each share being 100l. The rate of tonnage is 2d. per ton per mile on all goods, and 1d. per ton for passing the inclined-plane; manures, except lime, being exempt on the pounds, but not to pass the locks when the water is $\frac{1}{2}$ an inch under the lock-weirs. The profits of this concern are not to exceed 8 per cent. on the capital, after which the toll on boats for passing the plane is to be first lowered or taken off. The act in providing for the purchase of $1\frac{1}{4}$ mile of Mr. *Reynolds*'s Ketley canal as above, requires him to pay 2d per ton per mile afterwards for navigating the same, as above. Less than 8 tons in a boat, except in returning, is to be paid for as such.

Shropshire Canal. Act 28 Geo. III.—The general direction of this canal, or rather system of water-levels and inclined-planes, is nearly north, about $7\frac{3}{4}$ miles, in the county of Salop: its northern end is greatly elevated, and at no great distance from the grand-ridge on its western side; its objects are the export of coals and iron, and the carrying up of lime-stone. It communicates near Oaken-Gates with the *Shrewsbury* canal; it has no large town near it. It commences in the *Severn* river at Coal-Port, (a new town established by the late excellent Mr. *William Reynolds*, whose rapidly increasing manufactories in the year 1800 employed 400 persons,) and terminates in the *Donnington-Wood* canal at Donnington-Wood. It has a branch from Southall Bank, which proceeds to Brierly Hill near Coalbrook-dale ($2\frac{3}{4}$ miles), and thence is continued by an inclined plane and rail-way below, to the *Severn* at Loads-Croft, near the Brosley iron bridge. There is also a short rail-way branch to Horse-Hay iron works. At the *Severn* river at Coal Port (formerly called Sheep-wash Meadow) there is a flood-lock, which rises sufficient to clear the highest floods in the river, parallel to which the canal proceeds on a level, $\frac{3}{4}$ of a mile, to near Hay, where is an inclined plane of 350 yards long and 207

feet perpendicular rife; thence to near Windmill Farm, 1¼ mile, is level canal, where is another inclined plane of 600 yards in length, and 126 feet perpendicular rife; thence to the Brierly branch at Southall-Bank, 2¾ miles, is level canal; thence to the *Shrewfbury* canal at Oaken-Gates, 3 miles, is level; thence to near Wrockardine-Wood, 1¼ mile, is alfo level: at this place is a third inclined plane, of 320 yards in length and 120 feet perpendicular fall; thence to the *Donnington Wood* canal, 100 yards, is level. The boats are fhallow, and carry 5 tons. There are no locks on this canal, which is fupplied with water by two fmall refervoirs which lie above the canal, and two others below its level, the water therefrom being pumped up by the fteam engines belonging to the inclined planes; the waters which are lifted from the mines contribute alfo materially to the fupply of the different lengths of canal. The three great inclined planes at Hay, Windmill, and Wrockardine, have each a fhort inclined plane defcending from their tops into the upper canals, up which the boats, on a proper wheeled carriage, are dragged by the fteam-engines, working the wheels, drums, and ropes, and are, by the afcent of another boat, or the operation of a brake-wheel, let eafily down the long plane, as has been particularly defcribed already in this article. At Brierly-Hill the crates or iron bafkets of lime-ftone were drawn up, and the coals in boxes were let down, through perpendicular fhafts, 120 feet deep, by ropes winding on a drum above; but feveral years ago this plan was laid afide, and an inclined plane, fimilar to the three others above, except that it has no fteam-engine, has been adopted, as before mentioned. Six boats have been paffed down, and as many taken up, the Windmill plane of 600 yards long, in the courfe of a fingle hour; the fteam-engine and 3 men only being employed. It is faid that only 3d. is charged for letting down a loaded boat, and empty ones are returned gratis. Mr. *William Reynolds* and Mr. *Henry Williams* were the engineers; and the works were completed, and the canal opened in the year 1792; it is faid to have coft only 47,500l. The rate of tonnage is 2d. per ton per mile on all kinds of goods. In the year 1797, the tolls produced a net profit of 6 per cent. on the capital.

Sirhowy Rail-way. Act 42 Geo. III. (for *Monmouthfhire canal*).—The general direction of this rail-way or tram-road is nearly N. W., for about 28 miles, in the counties of Monmouth, and of Brecknock in South Wales: its northern end is much elevated: its object is the export of coals and iron from the rich mineral country through which it paffes: at Court-y-billa farm, and at Rifca, it is joined by rail-way branches of the *Monmouthfhire* canal. Newport is a confiderable town near its fouthern extremity: it commences at the *Ufke* river, near Pill-Gwenlly (oppofite the commencement of the *Monmouthfhire* canal), and terminates at Trevil lime-ftone quarries, in the parifh of Llanguinider; and it has a branch to Rumney union iron works; the line paffing through Sirhowy and Tredegar iron works, and through Tredegar park; it was faid alfo, that a branch of the rail-way was to be conducted from near Tredegar park to the meadows near the *Severn* river, where a new fea-port town, to be called New Amfterdam, was laid out and begun. This company were authorifed to raife 45,000l., the amount of their fhares being 100l., and they have engaged to pay 110l. annually to the *Monmouthfhire* canal company, on condition of their conftructing the firft 9 miles of this tram-road neareft to *Ufke*; fir *Charles Morgan* is to make 1 mile in length of the fame through his park at Tredegar, and receive the tolls thereon; and Meffrs. Samuel Homfray, Richard Fothergil, Matthew Monkhoufe, William Thompfon, William Forman, and other iron-mafters, are alfo to conftruct particular parts of this concern. It was provided, that if thefe feveral parties failed to execute their feveral parts of the line, previous to Michaelmas day 1803, that the act, as far as relates hereto, fhould be void. A new turnpike road is made by the fide of this rail-way for 21 miles: the afcent of the rail-way is fo eafy and regular that one horfe can draw 10 tons down the line, and return with the empty trams. A new town was laid out and begun at Tredegar new iron works, near Suhowee.

Sleaford Navigation. Act 32 Geo. III.—The general direction of this navigation is nearly weft, for about 12 miles, in the county of Lincoln: it is but little elevated above the fea, the greater part of it being embanked on both fides through level fens: its objects are the fupply of Sleaford and the furrounding country with coals, deals, &c., and the export of farming produce. Tatterfhall and Sleaford are confiderable towns near this navigation. It commences in the old *Witham* river at Chapel-Hill (not far from the commencement of *Horncaftle* canal), and terminates at the caftle-caufeway near Sleaford. The locks are 60 feet long, and 15 feet wide in the clear; the width of the canal is 30 feet at top, 18 at bottom, and four feet deep, except the fummit pound from Haverholm mill to Sleaford, which is to be 5 feet deep, to make a referve of water, which is to be fupplied from the fens above the navigation in New Sleaford. This company was authorifed to raife 23,000l., the amount of fhares 100l. each. The tolls are various for different parts of the line. See *Phillips*'s 4to. *Hiftory*, *Appendix*, p. 26. Lime, manures, and road-materials pay only half the rates of other articles. The profits of this concern are limited to 8 per cent. and after 1000l. is accumulated as a fund for contingencies, the tolls are to be lowered. This company are to join with the *Horncaftle* canal company, in the expence of improving the old *Witham* river between Lincoln high bridge and the *Fofs-dyke* navigation at Brayford-Meer; in confequence of which only half the ufual tolls on the old *Witham* are to be taken, on goods paffing to or from thefe navigations.

Soham Lode. The direction of this navigable cut or lode is nearly S. E., for about 4 miles, and is embanked through the level fens in Cambridgefhire: it commences in the great *Oufe* river, near Barway chapel, and after paffing through Soham-Meer, terminates at the town of Soham: its objects are the fupply of coals, &c. to Soham, and the export of farming products.

Somersetshire Coal Canal. Acts 34, 36, and 42 Geo. III.—The general direction of this canal is nearly S. W., for about 10 miles, befides a principal branch of 7½ miles nearly parallel thereto, in the county of Somerfet: its weftern ends are confiderably elevated: its object is the export of coals from the mines north of Mendip hills. Bath is the 12th Britifh town, with a population of 32,200 perfons, and Bradford the 78th., with 7,302 perfons, which are the only large towns near this canal; which commences in the *Kennet and Avon* canal, at Monkton Coombe, and the main or Dunkerton line of canal terminates at Paulton; but a rail-way continues it forwards to Tyning; the Radftock line or branch of canal proceeds from the laft at Mitford mill, and terminates at Radftock town; but a rail-way continues it forwards to Welton colliery; there are alfo rail-way branches from this line to Radftock colliery, and to Smallcombe and Clandon collieries: from the main or Dunkerton line, there are rail-way branches to Mearns, Amefbury's, Britton's, Salifbury's, and Radford collieries. From the *Kennet and Avon* canal to Mitford mill is level, thence the main or Dunkerton line

rises 138 feet by 22 locks. The Radstock line rises about the same height from Mitford mill. The boats used are 72 feet long, and 7 feet wide. About July 1796, Mr. *Robert Weldon* began the erection of one of his diving or caisson locks at Coombe-Hay, for passing the boats through a perpendicular shaft, either in ascending or descending. In November 1797, this apparatus was in sufficient forwardness for the caisson to be sunk and raised again in the shaft; and, in May 1798, a trial was made of this contrivance, so successful, that the inventor then offered to undertake to pass 1500 tons of goods in 12 hours through this 45 feet rise or fall, without the loss of any considerable quantity of water, and with the assistance of only one man, besides the bargemen, to work the machinery. These fair prospects were, however, blasted, by the bulging of the walls of the shaft, as we have already mentioned, in describing this contrivance; and inclined planes were constructed at this place for letting down boxes full of coals, the descent of which, by means of ropes and wheels, drew up the boxes, either empty, or in part loaded with other goods: the delay and expence of this method being highly complained of, about September 1802, a new subscription was set on foot, and encouraged by the *Kennet and Avon* and *Wilts and Berks* companies, for substituting locks, 22 of which were completed, and opened on the 5th of April last (1805). Mr. *John Rennie*, Mr. *William Bennet*, Mr. *Charles Wedge*, and Mr. *William Smith* were the engineers consulted or employed upon this canal, which, in January 1801, was completed from Dunkerton to several of the coal mines, and which, (after 4 miles of land carriage.) had the effect of lowering coals at Bath from 14d. or 15d. per cwt. to 9d or 10d. This company was authorised to raise 185,000l., the amount of shares 100l. each. Before undertaking any of the rail-way branches to the collieries, this company might require security from the owners of such collieries, that the tolls thereon should produce, or be made up, to a certain rate of interest on the cost of such branches. The profits of this concern are not to exceed 10 per cent.; but after 1000l. is accumulated and placed in goverment securities, as a fund for contingencies, the tolls on coals are to be lowered. Husbandry and pleasure boats 12 feet long and 5 feet wide may be used toll free on the pounds, or where the water flows waste over the lock-weirs. A tunnel, $\frac{3}{8}$ of a mile long, was at first proposed near Coombe-Hay, but by a subsequent alteration of the line this was avoided. The rates of tonnage in the first act may be seen in *Phillips*'s 4to. *History, App.* p. 163 and 164, including the tolls on horses, cattle, sheep, &c. travelling on the rail ways; by the last act some of the tolls were increased. Dunkerton mill was purchased by this company, and steam-engines were erected to pump up water for supplying the upper pounds. In several places this canal was cut through *strata* disposed to slip, but by the small tunnels or soughs which Mr. *William Smith* constructed, for draining off the springs, the same was prevented. On the 3d of May, 1804, a sudden and great flood happened, which required, it was said, some of the banks of this canal to be cut in proper places, to give vent to the water.

Southampton and Salisbury Canal. Acts 35 and 40 of Geo. III.—The general direction of this canal is nearly N.W. for about 17 miles, in two detached lengths, in the counties of Hants and Wilts; it is not greatly elevated; its objects are the trade between Southampton and Salisbury, the supply of these towns, and the export of the surplus farming products of the intermediate country. This canal commences in the *Itchin* river, at Northam near Southampton, and proceeds along the N.E. shore of *Southampton water* to the *Andover* canal at Red-bridge. In the *Andover* canal (about $9\frac{1}{2}$ miles above Red-bridge), near Kimbridge mill, this canal commences again, and proceeds to the *Avon* river at Salisbury, or New Sarum. Southampton is the 68th British town, with a population of 7,913 persons, and Salisbury is the 70th, with 7,768 persons: Romsey is also a considerable town near this line. The eastern part of this canal, between Northam and Red-bridge is level, and but little elevated by its tide-locks, above the tide-way in *Itchin* river and *Southampton Water*; from its skirting along close to the shore of the latter river, it was that that facetious satirist *Peter Pindar* took occasion to burlesque "Southampton's wise sons." Upon this part of the canal there is a tunnel of considerable length close to, and indeed under part of the north end of Salisbury town; considerable difficulties seem to have attended the making of this tunnel, owing to the looseness of the soil; and the quick-sands at the foot of the cliff, by the side of *Southampton Water*, have also proved a very serious obstacle. An aqueduct is built over Shirley Brook; springs within 1000 yards of the canal may be taken for its supply, which is also to be aided by some reservoirs, which were begun in 1796. This company have been authorised to raise 90,000l the amount of each share being 100l. Mr. *John Rennie* is the engineer; the eastern part of the canal was begun in 1796, and was said, in 1803, to be nearly done, but it is not yet opened. The western part from the *Andover* canal at Kimbridge was completed to Deane, in October 1798. Stones are to be erected on the banks of this canal, at every $\frac{1}{4}$ of a mile distance.

Southampton Water. Acts 11 Henry VII. and 18 Henry VIII.—This noble estuary of the Anton and other rivers has a N.W. direction for about 10 miles in Hampshire. The tide flows through its whole length, and through a branch thereof more than 5 miles in length to near Botley; *Southampton water* is navigable for large ships; it commences in the channel between Hampshire and the Isle of Wight at Calshot Castle, and terminates near Red-bridge where it is joined by the Anton river (formerly navigable near 6 miles to Romsey), and the *Andover* canal near one of the terminations of the *Southampton and Salisbury* canal; near Salisbury it is joined by the *Itchin* river, (about $\frac{3}{4}$ of a mile from the commencement of the *Southampton and Salisbury* canal.) In the 43d of Geo. III., an act passed for enlarging and improving the quay and harbour of Southampton, by building a pier and other works which commenced in December 1803, and have since been proceeding.

Staffordshire and Worcestershire Canal. Acts 6, 10, and 30, of Geo. III.—The general direction of this canal (sometimes called the Wolverhampton canal) is nearly north for $46\frac{1}{2}$ miles in the counties of Worcester and Stafford; its middle part is very considerably elevated, and it crosses the grand-ridge without a tunnel; its trade in the export of coals, pottery-wares, hard wares, &c. is immense, besides the general trade between the *Severn*, the *Mersey*, and *Trent*, which for a long time passed exclusively through it. Near to Stourton, and to Stewponey, it is joined by the *Stourbridge* canal, and at Aldersley or Autherley by the Old *Birmingham* canal. Wolverhampton is the 33d British town with 12,565 inhabitants, and Kidderminster is the 95th with 6,110 persons: Bewdley, Stourbridge, Penkridge, and Stafford, are also considerable towns on or near to this canal; which commences in the *Severn* river at Stourport, and terminates in the *Trent and Mersey* canal at Great Haywood. From the *Severn* river at Stourport, to the *Stourbridge* canal at Stewponey, $12\frac{3}{4}$ miles, is a rise of $127\frac{1}{2}$ feet by 13 locks; thence to Tettenhall, the beginning

of the ſummit-pound, 11 miles, is a riſe of $166\frac{1}{2}$ feet by 18 locks; thence to the old *Birmingham* canal, $1\frac{1}{4}$ mile, is level; thence to Street-way, $8\frac{3}{4}$ miles, is level to the N. end of the ſummit-pound; thence to the *Trent and Merſey* canal at Haywood, $13\frac{1}{4}$ miles, is a fall of $100\frac{1}{2}$ feet by 13 locks. This canal is 30 feet wide at top, and 5 feet deep, though the depth of water on the lock-ſills is only 4 feet. The locks are 74 feet long and 7 feet wide; and ſeveral of them are built of a red kind of free-ſtone; the boats in general carry 20 tons. At Stourport are two baſons belonging to this canal connected with the Severn river by flood-locks to keep the water in them always at one certain height. On this canal are three ſhort tunnels; one is near to Stewponey, the other at Whitlington, and the other is an arched-way under part of the town of Kidderminſter; at which place there is an aqueduct-bridge over the Stour river, another at Preſtwood on Wordſley brook, another near Milford on the Sow river, and another at Haywood mill over the Trent river. In Chillington is a large reſervoir, and at Moſeley another, whoſe waters are conveyed to the ſummit-pound by feeders of conſiderable length. This company may make branches to any place within 1000 yards of the line by conſent of the land-owners. Mr. *James Brindley* was the engineer to this canal, which he began in September 1766, and finiſhed in 1772. The firſt lock which this engineer erected was at Crompton, on this canal. This company were authoriſed to raiſe 100,000l., the amount of each ſhare being 100l. In September laſt (1805), the yearly dividend on theſe was ſtated to be 24l. The rates of tonnage are ſtated (in Mr. *John Cary*'s excellent work with maps, now publiſhing in numbers, on Inland Navigation,) to be $1\frac{1}{2}$d. per ton (2400lb.) per mile on all kinds of articles except lime and lime-ſtone, which pay only $\frac{1}{2}$d. per ton; and paving and road materials, and manures for adjoining lands which are to paſs toll free on the pounds, and through the locks when the water flows over the lock-weirs. By the *Dudley* act (16 Geo. III.), coals brought from that canal and carried on this may be charged 2d. per ton per mile, but commiſſioners may authoriſe lowering this toll. The uſual charge made by bargemen in 1796 for freight (including the company's tonnage) was, for periſhable goods $2\frac{1}{2}$d. per ton per mile, and for heavy unperiſhable goods 2d. In 1802, a tunnel 5 feet in diameter and 135 feet long, compoſed of cylinders of caſt-iron, was laid under the river Penk near this canal for draining a moraſs of 500 acres. In the laſt ſeſſions (45 Geo. III.) application was made by this company for a new act, to raiſe the tolls in order to make new locks, the old ones in ſome places being decayed and nearly worn out, and for making ſome new rail-way branches. The *Stour* river between Stourport and Stourton, by the ſide of this canal, was made navigable ſeveral years ago, but the works thereon were ſoon after deſtroyed by a great flood. In the preſent month (November 1805), a rail-way branch from Latherford in Shareſhill is propoſed, to Mr. Henry Vernon's collieries in Buſhbury.

Stainforth and Keadby Canal. Acts 33 and 38 of Geo. III. The general direction of this canal is nearly W.; for 15 miles in the counties of Lincoln and York, it has its courſe through level fens and is but little elevated above the level of the ſea; its objects are the import of coals and export of agricultural produce, with a better drainage of the country through which it paſſes. Thorne is the only conſiderable town near this line; which commences in the *Trent* river at Keadby, and terminates in the *Don* river at Fiſhlake near Stainforth, having alſo a branch 1 mile in length which joins the *Don* river at Hangman-Hill in Thorne; the whole is on one level, having tide or flood-locks at its extremities to regulate its height notwithſtanding the variable tides and floods in the adjoining rivers. A reſervoir of 5 acres is conſtructed on Thorne Common, and the waſte water from this canal is to be diſcharged into the *Trent*. In 1762, when Mr. *John Smeaton* was conſulted about the drainage of Potterick Car, a navigable canal through theſe fens was in contemplation. This company were authoriſed to raiſe 54,200l., the amount of ſhares being 100l. each.

Stoke River. The direction of this river (ſometimes called the Winſon) is W. for about $8\frac{1}{2}$ miles in the county of Norfolk; it is embanked nearly its whole length through the fens, and is but very little above the ſea; its objects are the import of coals, deals, &c. and the export of agricultural products. Downham is the only conſiderable town near it; it commences in the Great *Ouſe* river between Denversſluice and Salters-Load, and terminates at Stoke-Ferry near the town of Stoke.

Stort River. The general direction of this river is almoſt N.E. by a bending courſe of about 13 miles between the counties of Eſſex and Hertford; its northern extremity is conſiderably elevated; its objects are the import of coals, deals, &c. and the export of farming products. Hoddeſdon and Biſhopſtortford are conſiderable towns near this river; which commences in the *Lea* river near Hoddeſdon, and terminates at Biſhopſtortford. In 1785, this navigation was propoſed to be joined at its northern end by the *Biſhopſtortford and Cambridge*, and in 1789, it was intended to join the *Biſhopſtortford and Wilton* at the ſame place.

Stour River (*Chriſtchurch*.) The direction of this river is nearly N.W. for about 35 miles in the counties of Hants and Dorſet; its northern end is conſiderably elevated; its objects are the import of coals, deals, &c. and the export of farming products; Chriſtchurch, Wimborn-Minſter, Blandford-Forum, and Sturminſter-Newton, are conſiderable towns on this river; which commences in the tide-way in Chriſtchurch-bay at Chriſtchurch-harbour, and terminates at the town of Sturminſter. At Gains-croſs in Shillington-Okeford, it is to be joined by the *Dorſet and Somerſet* canal. In 1762, Mr. *John Smeaton* was conſulted on the intended improvements in Chriſtchurch-harbour; the ſpring-tides in this harbour flow only 5 to 7 feet, and the neap-tides no more than 4 to 6 feet; and 3 hours after high water there is a ſecond or ſmaller tide, which flows in the harbour from 8 to 18 inches, being greateſt at the neap-tides. In the reign of Charles II., a pier of 256 yards in length, was conſtructed of lumps of iron-ſtone out of the looſe ſandy-cliff near it, and Mr. *Smeaton*, in 1764, planned another pier to be built for the better ſecurity of this harbour.

Stour River (*Harwich*.) The general direction of this river is nearly W. by a bending courſe for about 29 miles between the counties of Eſſex and Suſſex; the firſt 10 miles is a wide eſtuary through which the tide flows, the weſtern end is not greatly elevated; its objects are the import of coals, deals, &c. and the export of farming products; Harwich, Manningtree, Neyland, and Sudbury, are conſiderable towns on this river; which commences in the *Stowmarket and Ipſwich* navigation (near its junction with the German Ocean) at Harwich, and terminates at Sudbury.

Stour River (*Sandwich*.) Act 7 Henry VII.—The general direction of this river is nearly W. by a crooked courſe of about 18 miles in the county of Kent; it is but little elevated above the ſea in any part; its objects are the ſupply and trade of Canterbury, and the export of farming products. Canterbury is the 57th Britiſh town with a population of 9,000 perſons, and Sandwich is the 93d with 6,506 perſons, Ramſgate is alſo a conſiderable place near to this river; which commences in the Engliſh Channel or

Downs at Sandwich Haven (1½ mile from Ramsgate-harbour), and terminates at the city of Canterbury; the lower end of this river, for 1½ mile in Pegwell bay, has its course through shifting sands which are dry at low water, and covered at high water; it is therefore unsuited for large vessels to enter, and *Ramsgate harbour* is the only secure retreat for ships in case of a storm on this part of the coast. The celebrated piers which form this harbour were begun in 1749; the southern pier extends 800 feet eastward into the sea, it then returns northward, forming the front next the Downs, by a polygon of 5 sides, each 450 feet in length; these are joined at their angles by octagons of solid masonry that are 60 feet across; the breadth of the pier at top including the parapet is 26 feet, and the whole is built of hewn Portland and Purbeck stone. The entrance for ships is from the north nearly, and is 200 feet wide, having a light-house with Argand's reflecting lamps on its west head, and this is connected with the shore by a similar, though short pier, as on the southern side. The area of the famous harbour, thus formed in the open sea, is 46 acres, and it is deep enough to receive ships of 4 or 500 tons burthen. A spacious dry-dock for the repair of ships connects with this harbour. In a few years after the piers were completed, this harbour was nearly choaked with mud deposited by the tides. Mr. *John Smeaton*, who was consulted, erected a cross-wall at the uppermost extremity of the harbour with numerous sluices therein, by the drawing of which, after the tide has retired and left this reservoir full of water, the mud has been since effectually scoured out; this excellent engineer also extended the pier 400 feet at the head. Nearly 300 ships have been known at once to assemble in this harbour for shelter on the approach of a storm. An act 5 Geo. III., passed for improving this harbour as above, and by 37 Geo. III. the tonnage charged on vessels passing the English Channel for the support of Rye-harbour, was transferred to this harbour as before mentioned. In the years 1802 and 1804, the *Canterbury and Nicholas-bay* canal was intended to join the *Stour* river at Canterbury; and in 1802, the *Medway and Rother* canal was proposed to join it near the same place.

Stour River (*Stourbridge*.) Many years ago the *Stour* river from the *Severn* at Stour-port to the town of Stourbridge, (passing the town of Kidderminster,) about 14 miles, was made navigable by means of sluices, weirs, and other works; but soon after there happened so sudden and violent a flood as to destroy all these works. The *Stafford and Worcester*, and the *Stourbridge* canals, have since supplied more effectually the place of this river navigation.

Stourbridge Canal. Acts 10 and 22d of Geo. III. The general direction of this canal is nearly E. by a crooked course of about 5 miles in the county of Stafford; its eastern end is considerably elevated, and extends within about 3 miles of the grand-ridge on its eastern side; its objects are the export of coals, iron-stone, &c. and forming part of the communication between the Old *Birmingham* and the *Severn*, &c. Stourbridge and Dudley are considerable towns near this line; which commences in the *Staffordshire and Worcestershire* canal near Stourton and Stewponey, and terminates in the *Dudley* canal at Black-Delph; there is a branch of near 1 mile to the town of Stourbridge, and a branch of 2 miles to Pensnett-Chase reservoir, with a side-branch thereto of near ¾ of a mile in Brierly parish. From the *Stafford and Worcester* canal to near Stewponey, ⅛ of a mile, is a rise of 43¼ feet by 4 locks; thence to the Stourbridge branch, 2 miles, is level; thence to the Lays, 1¼ mile, has a rise of 148 feet by 16 locks; thence to the *Dudley* canal, 1½ mile, is level; the Pensnett and Brierly branches are level with the last or summit-pound, and the Stourbridge branch is level. The width of this canal is 28 feet, and the depth of water 5 feet. The Pensnett-Chase or Fen reservoir is 12 acres in extent, for supplying the head-level of this canal. This company were at first authorised to raise 30,000l. in 100l. shares; the last act authorised calling upon the subscribers for 7,500l. more, by which their shares are now increased to 125l each. The rates of tonnage will be found in Mr. *John Cary's Inland Navigation*, pages 50 and 51. Goods may be navigated on the summit-level toll free; and road-materials and manures for adjoining lands, may also be carried on any of the pounds toll free. Less than 15 tons are not to pass any lock without consent. Side-branches may be made to the adjacent collieries. The *Worcester and Birmingham* company were bound (act 31 Geo. III.) to make up the profits of this concern to 9 per cent per annum, in case of their canal lessening the trade hereon; but on the extension of the *Dudley* canal to join the *Worcester and Birmingham*, the last mentioned company were exonerated therefrom, and the *Dudley* engaged (33 Geo. III.) to make up the annual dividend on the shares in this concern to 12l. each; but not to exceed 3l., and this when their own canal yielded a dividend of 5l. per share. The part of this canal below Stourbridge supplies the place of the river *Stour* navigation, which was destroyed by floods as above mentioned. In 1786, the *Stourbridge and Worcester* was proposed to join this canal at Stourbridge; as was also a branch since proposed from the *Worcester and Birmingham*.

Stourbridge and Worcester. In 1786, a canal was proposed, and supported by the late lord *Dudley and Ward*, from the *Severn* river at Diglis below Worcester city to the *Stourbridge* canal at that place, passing Bromsgrove; its proposed length was 26 miles with 772 feet of lockage, by 128 locks; some tunnels and other large works were necessary; a bill for this canal passed the commons, but was rejected by the house of lords.

Stover Canal. Act 32 Geo. III.—The general direction of this canal is nearly N.W. for 6½ miles in the county of Devon; it is but little elevated; its objects are the import of coals, shelly sea-sand and lime, as manures, and the export of potters' clay (used in Staffordshire, Lancashire, &c.) and a peculiar kind of imperfect coal found in small quantities at Bovey-Tracey; Newton Bushel and Chudleigh are considerable towns near this canal, which commences in the tide-way in the *Teign* river at Newton Abbots, and terminates at Bovey-Tracey, with a branch of 5¼ miles to the town of Chudleigh. From Newton-Abbots to Newton-Bushel, 1 mile, is a rise of 20 feet; thence to Bovey, 5½ miles, is 30 feet rise; the Chudleigh branch is level. *James Templer*, esq. is the sole proprietor of this canal, and Mr. *Gray* was his engineer. At Teigngrace, and the adjoining parishes, the surplus water of this canal has been applied to the irrigating of the lands below it, a capital improvement, which we are very anxious to see more generally adopted.

Stowmarket and Bury Rail-way. In December, 1802, it was in contemplation to make a rail-way from the *Stowmarket and Ipswich* navigation at Stowmarket, to the *Lark* river at Bury St. Edmunds, for the purpose of supplying the latter place, and the intermediate country with coals; (the *Lark* navigation being often interrupted by droughts in the autumn;) and for the readier export of farming products.

Stowmarket and Ipswich Navigation. Acts 33 and 45 Geo. III.—The general direction of this navigation (which follows the course of the Orwell river) is nearly N.W. for about 26 miles, in the county of Suffolk, the first 13 miles, to near Ipswich, being a wide channel or estuary in the tide-way, the remainder is not greatly elevated; its objects are the import of coals, deals, &c. and the export of

farming products; it is joined by the *Stour* river near Harwich. Ipswich is the 41st British town, with a population of 11,277 persons. Harwich, Needham, and Stowmarket are also considerable towns near this navigation; which commences in the German ocean at Landguard fort, and terminates at the town of Stowmarket. This company were, by an act prior to the above, authorised to raise 14,300l. by the first act above 15,000l. more might be raised; the last act was for improving the port of Ipswich by deepening the same, so that ships might unload at the wharfs, &c. In December, 1802, it was proposed that the *Stowmarket and Bury* rail-way should join this navigation at Stowmarket.

Stratford Canal. Acts 33, 35, and 39 Geo. III.—The general direction of this canal is nearly N. for $23\frac{1}{2}$ miles, in the counties of Warwick and Worcester; it is very considerably elevated, and crosses the grand-ridge: its objects are the export of coals, lime, and paving-stones, and as a link in the great chain of canal communication; at Kingswood in Rowington a branch of this canal connects with the Warwick and Birmingham: Stratford-upon-Avon and Henley are considerable towns on or near this canal, which commences in or near the *Avon* river at Stratford, and terminates in the *Worcester and Birmingham* canal at King's Norton, about 6 miles from Birmingham. From near Hockley there is a branch $2\frac{1}{4}$ miles long to Tanworth quarries; from near Lapworth there is another branch of $1\frac{3}{4}$ miles to the *Warwick and Birmingham* canal; and from near Wilmcote is a branch of 4 miles to Temple-Grafton lime-works, with a branch of about 1 mile from this cut to Aston-Cantelow. From Stratford to near Copnas-hill, $1\frac{1}{2}$ mile, is level; thence to Wilmcote, 1 mile, has a rise of 86 feet; thence to Preston-mill, 6 miles, is level; thence to Preston-green, $1\frac{3}{4}$ mile, is a rise of 76 feet; thence to Lapworth-hall, 1 mile, is level; thence to Hockley Heath, $2\frac{1}{4}$ miles, is a rise of 147 feet; and thence to the *Worcester and Birmingham* canal, 10 miles, is level; the Tanworth branch is level, and connects with the summit-pound: the Temple-Grafton cut is level for the first $2\frac{1}{2}$ miles, and in the next $1\frac{1}{2}$ mile the rise is 20 feet. Near Milepole hill is a tunnel of 320 yards in length; there are several small aqueduct bridges; and some deep-cutting near Waring's Green. In May 1796 the summit-level of this canal from the *Worcester and Birmingham* canal to Hockley-heath was completed and opened. This company was authorised to raise 225,000l. the amount of shares 100l. The rates of tonnage and exemptions are very long; see *Phillips*'s 4to. *History, Appendix*, p. 111 and 112. At the junction with the *Worcester and Birmingham* canal stop-gates are to be erected, to be shut and locked by either company, when the supplies of the other canal fail in dry seasons; with the *Dudley* and *Worcester and Birmingham* canals there are a number of regulations as to tonnage, in the second act above (35 Geo. III.). About the year 1792 the *Stratford and Croperdy* canal was proposed to join this at Stratford.

Stratford and Croperdy. About the year 1792 a canal was proposed to connect with the *Avon* river and *Stratford* canal at Stratford, and proceed to the *Oxford* canal at Croperdy, by a course of about 31 miles in length; this being the southern part of the proposed line between Dudley and Croperdy; the northern part thereof being since occupied by the *Stratford* and the *Dudley* canals.

Stroudwater Canal. Acts 34 Geo. II. 15 Geo. III. 23 (for *Thames and Severn*,) and 33 and 37 Geo. III. (for *Gloucester and Berkley*).—The general direction of this canal is about E. for 8 miles, (following nearly the course of *Stroudwater* river,) in the county of Gloucester; it is not [illegible]tly elevated; its objects are the import of coals, and [illegible]g part of the first direct communication between the *Severn* and *Thames and Isis* rivers; at Wheatenhurst the *Gloucester and Berkley* canal crosses and connects herewith. Stroud is the 114th British town, with a population of 5,422 persons. This canal commences in the *Severn* river at Framiload, and terminates in the *Thames and Severn* canal at Wallbridge near Stroud; from the *Severn* to the *Thames and Severn*, there being a rise of 108 feet: this canal is wide enough for the Severn river boats. The engineers were Mr. *Thomas Yeoman* and Mr. *Robert Whitworth*. The first of the above acts was for powers to raise 20,000l. in 200l. shares, intending to execute the works under the powers of an act of 2 Geo. II. for improving the *Stroudwater* river, but several expensive law-suits put a stop to the works, as we have already mentioned, until the second act was obtained: a double lock of 14 feet rise on this canal had a slipping bank of earth 20 feet high by its side, and gave immense trouble, to prevent the walls thereof being bulged in, this was at last accomplished by the turning of two dry drains of four feet diameter, between the lock and the bank. In 1802 the dividends on shares in this concern were 6l. each, and their price was about 225l. This canal has no horse towing-path, but stiles are erected thereon, and the barges are hauled by men. Where this canal crosses the *Gloucester and Berkley*, stop-gates are to be erected to prevent this canal from losing its water; no dues are to be taken for vessels crossing either of these canals. If, while the *Gloucester and Berkley* is cutting, the navigation of this canal is interrupted, five guineas per day are to be paid to this company; vessels passing to or from the *Berkley and Gloucester* canal and this, are to pay the same tonnage as to and from the *Severn* at Framiload. This company are authorised to take 2s. 3d. per ton for coals which pass through this canal, and on the *Thames and Severn* canals, but not beyond Brinscomb bridge thereon, and for such coals as pass eastward of Brinscomb bridge, 1s. per ton.

Stroudwater River. The act of 2 Geo. II. passed for making this river navigable between the *Severn* and the town of Stroud, a distance of about 8 miles, as above; but the opposition of the millers and others prevented its being accomplished, until 34 Geo. II. when Mr. *Bridge* undertook to construct the navigation, without waste of water or prejudice to the mills, by means of cranes to hoist the goods in boxes out of the boats in one pound, and place them in others in the adjoining pounds, as we have before described; but this scheme miscarried, and the projectors were nearly ruined: at length the *Stroudwater* canal was constructed by the side of this river as above.

Surrey Iron Rail-way, (*Northern part*). Acts 41 and 45 Geo. III.—This, the first public rail-way constructed near the metropolis, has about a S.E. direction, for 10 miles, in the county of Surrey: its southern end has a considerable elevation: its objects are the import of coals and manures, and the export of chalk, flint, fire-stone, fullers'-earth, and agricultural products. Croydon is the 108th British town, with a population of 5703 persons; Wandsworth is also a considerable town on this line; which commences near the tide-way in the river *Thames* at Wandsworth, and terminates at the turnpike-house S. of Croydon, in the southern part of the *Surrey iron-rail-way*; at the N.W. extremity of Croydon the line of this rail-way is but about $\frac{1}{4}$ of a mile from the *Croydon* canal; from Mitcham common a branch goes off for about $1\frac{1}{2}$ mile to Mr. *Shipley's* skinning mill at Carshalton; and, to Messrs. *Were* and *Bursh*'s oil-mill, about $\frac{1}{4}$ of a mile, there is another branch at Garrat-lane. This rail-way has nowhere a greater ascent than about 1 inch in 10 feet: it is double throughout, with numerous crossing places for the carriage out of one road or track into the

other; of these we have already given a particular account, as also of the contrivances for shooting the contents of the rail-way waggons, on some occasions, into barges lying in the entrance bason at Wandsworth, which is about ¼ of a mile long, with a lock next the *Thames*, and is spacious enough to hold 30 barges or more at once, several of which can lie along the wharf to load or unload at the same time. The width of each track is about 5½ feet, the waggons carry about 3¼ tons each, and several of them are often linked together to be drawn by one horse. This rail-way crosses the Wandle river twice on wooden bridges. On the 9th of January, 1802, the entrance bason at Wandsworth was completed and opened; in October of the same year, the rail-way from the side thereof crossing the turnpike road, and extending to Garrat was completed, and in the course of the present year it was opened to Croydon. The company were, by the first act, authorised to raise 50,000l. and a further sum, by the act of the late sessions, the amount of shares 100l. Few subjects have been more variably stated than the cost per mile of this rail-way. Mr. *John Phill'ps*, after noticing in his *History* the commencement of this work, adds, that iron rail-ways are made at an expence of about 300l. per mile. The original estimate was, we believe, 2000l. per mile; at a public meeting at Gosport, in September 1803, it was stated by some favourers of the extension of a canal from Croydon to Portsmouth, that the expenditure on this rail-way had amounted to 6,400l. per mile; but the advocates for extending this rail-way to Portsmouth instead of a canal, then contended that the expence did not exceed 4,500l. per mile; while Mr. *James Malcolm*, in his Agricultural Report on Surrey, just published, after stating the great pains he had been at to come at the facts, says, "instead, therefore, of the expence being 2000l. per mile, it appears as if it would be 7000l.!" (this includes all the expenditure of the company). The rates of tonnage are from 2d. to 6d. per ton, per mile, for different goods; and owners of adjoining lands may use the rail-way as a drift road. Ten pounds annually are to be paid to the city of London by this company, for connecting with the river Thames.

Surrey Iron Rail-way) (*Southern part*). Act 43 Geo. III.—The general direction of this line of rail-way is nearly S. by a bending course of about 16 miles, in the county of Surrey; upon the chalk-hills or North Downs, it is greatly elevated; its objects are the import of coals and manures, and the export of chalk, lime, fire-stone, free-stone, flints, fullers'-earth, and agricultural products. Croydon is the 108th British town, with a population of 5,743 persons; Ryegate and Godstone are also considerable towns on or near this line, which commences in the northern part of the *Surrey iron rail-way* at Croydon turnpike, near the southern end of that town, and terminates at Godstone, passing near to the towns of Merstham and Ryegate in its course. It has a rise or fall of 1 inch in 10 feet, in crossing the Downs: near to Merstham is a considerable length of cutting 30 feet deep in some places, in order to obtain the proper descent; at Smitham-bottom is an embankment of 20 feet high, across a valley, for the same purpose, with a road-arch under it; it crosses the Croydon and Merstham road in another place by an arch, and the road is sunk considerably in order that the rail-way with its proper descent may pass over it. The width of this double rail-way, including a path on each side for the carriage drivers is 24 feet. Some of the waggons hereon have their fore-wheels placed quite forward, and the hind-wheels nearly under the middle of the waggon, by which means stones, &c. can easily be shot out of them when required. Near to this rail-way at Merstham there is a quarry of white soft free-stone (much similar to the Totternhoe-stone on the *Grand-Junction* summit branch). The shares in this concern are 100l. each. In September, 1801, it was in contemplation to make a branch of this intended rail-way from near Ryegate to the *Arun* river at Wisborough green; and another branch or rather an extension hereof, from near Godstone to the *Ouse* upper navigation at Linfield. About the month of June last (1805,) this rail-way between Croydon and Merstham was opened, and 12 waggons loaded with stone, weighing 38½ tons, were drawn with ease by one horse for 6 miles down the descent to Croydon-turnpike, in 1 hour and 41 minutes; from which place the same horse set off again with 4 other loaded waggons attached, and persons riding on them, making in the whole more than 55 tons, which it was said he drew with apparent ease!

Swale River. The general direction of this river is nearly N.W. for about 35 miles, by a crooked course in the North Riding of Yorkshire. Its northern end is very considerably elevated, and this river is subject to rapid and almost uncontroulable floods: its objects are the carriage of coals, and the export of farming products. Aldborough and Richmond are considerable towns near, or on this river, which commences in the *Yore* river at Myton; and the navigation was intended to terminate at Richmond. In 1767, Mr. *John Smeaton* was consulted on the propriety of moving Topcliff mill to a new scite, in the design which the proprietors of this navigation had adopted of building new mills in several places, and on which it has been said that 30,000l. was expended, and but a small part of the above line was rendered effectually navigable. Mr. *John Smith* jun. was the resident engineer. In 1801, the *Topcliff and Piersbridge* was proposed to join at Topcliff.

Swansea Canal. Act 34 Geo. III.—The direction of this canal is about N.N.E. for 17½ miles in the counties of Glamorgan and Brecknock, in South Wales. Its northern end is considerably elevated: its objects are the export of coals and iron-stone, iron, &c. the carriage of lime to the intermediate works and country; and copper-ore, to the works, &c. Swansea is the 99th British town, with 6,099 inhabitants. This canal commences in Swansea harbour, in Swansea bay, at the mouth of the Tave river, and terminates at Hen-noyadd lime-works: a part of this line between Llandoor brook and Morris town, 1¼ mile in length, (called *Morris's canal*) through the estate of the *duke of Beaufort*, was constructed by that nobleman, who receives the tolls thereof. From near Swansea to Llansamlet is a branch of 3 miles in length; and a rail-way branch of about 2 miles to a large coal mine, where an audit or tunnel of 3 miles in length has been made under ground, and out of which 200 tons of coals are daily brought; on an inclined-plane on this branch, near 1 mile in length, the coal-waggons descend without horses, regulated by a convoy or brake, as we have before described, and the empty waggons are drawn up the plane again by horses. From the tide-way at Swansea to opposite Pont-ar-Taw, 8¾ miles, is a rise of 105 feet; thence to Pont Gwaynclawdd, 8 miles, is a rise of 230 feet; and thence ¾ of a mile to Hen-noyadd is a rise of 31 feet. An act 44 Geo. III. passed for amending two former ones, for building piers, and deepening and improving the harbour of Swansea, under the direction of captain *Joseph Huddart*. About the year 1797 the western pier, extending 228 yards into the sea, was completed; which had the effect of confining the current of the Tave river, and deepening the mouth of the harbour 2 feet: in 1802 this pier was extended 57 yards farther out, and in November 1804 a jetty thereto was completed. In April last (1805) a new pier was begun on the eastern side of the

harbour, which is to be extended out and brought round weftwardly, within 70 yards of the other pier, for effectually fecuring and fcouring the mouth of the harbour: dry and wet docks are alfo intended, and by embanking the river, a moft fpacious quay is to be formed. From this port, in 1768, only 694 fhips cleared out; in 1790 thefe were increafed to 1677 fhips, and in 1800 to no lefs than 2590 of 134,264 regiftered tons. Within 2 miles of Swanfea, feven large copper-works have of late years been erected, for fmelting of roafted ore from the Cornifh and Anglefea mines, brought in fhips, which return laden with coals for working the mine-engines and roafting the ore: the number of iron-furnaces, potteries, and other large works near this place are alfo confiderable. This canal company was authorifed to raife 90,000l., the amount of fhares 100l. each; and it was provided in the act, that this canal fhould be completed in 4 years; feveral rail-way branches may be made thereto. The engineer was Mr. *Thomas Sheafly*, and the canal was completed and opened in October 1798. The rates of tonnage may be feen in *Phillips*'s 4to. *Hiftory, Appen.* pages 166 and 167. Boats with lefs than 15 tons, when the water does, and 10 when it does not flow over the lock-weirs, are not to pafs without leave or paying for that tonnage. In the year 1804, 54,235 tons of coal and culver were brought down this canal for exportation, and the grofs tonnage on this canal amounted to 3590l. In Swanfea harbour, the *Swanfea and Oyftermouth* rail-way connects with this canal.

Swansea and Oystermouth Rail-way. Act 44 Geo. III.—The general direction of this rail-way is nearly S.W. by a bending courfe, following clofely the fea fhore, for about $7\frac{1}{2}$ miles in length in the county of Glamorgan, in South Wales: its object is the carrying of lime-ftone, lime, and coals. Swanfea is the 99th Britifh town, with 6,099 inhabitants. This rail-way connects with the *Swanfea* canal in Swanfea harbour, and proceeds thence to the Mumbles lime-ftone quarries near Oyftermouth. In April laft (1805) this rail-way was nearly completed. There is a light-houfe on the Mumbles point for the fecurity of fhips entering Swanfea harbour, which was lately improved.

Tamar Manure Navigation. Act 36 Geo. III.—The general direction of this canal is nearly N.W. for about 22 miles, following the courfe of the Tamar river, on the fouthern coaft of the counties of Devon and Cornwall. Its northern end is confiderably elevated: its objects are the import of coals, and fea-fand and lime as manures; and the export of agricultural products. Launcefton is the only confiderable town on this line; which commences in the tide-way in the *Tamar* river at Morwellham quay (the commencement of the *Taviftock* canal) near Callftock, and terminates at Tamarton bridge in North Tamarton, with a branch to Rich-mill grove in Launcefton. The *Tamar* is to be made navigable as far as Port-pool near Blanch-Down, before the canal commences. The locks are to be either about 5 feet or $9\frac{3}{4}$ feet wide, and $12\frac{1}{2}$, $24\frac{1}{2}$, or $36\frac{1}{2}$ feet long, in order to receive a number of fmall boats, in length and fide by fide therein, as may be judged beft. Inclined planes and rail-ways may be fubftituted in place of locks on the canal in any part. This company is authorifed to raife 121,000l., the amount of each fhare 50l. A feeder may be taken from the Tamar river, and all fprings within 2000 yards of the head level, and within 1000 yards of every other part of the line; 200l. per annum is to be paid by this company to the duchy of Cornwall, for the liberty of making this navigation. We have not been able to learn what progrefs has yet been made in the cutting of this canal. By the act 14 Geo. III. a canal was intended, but never executed, through this line, and extending to the Irifh Channel, called the *Bude and Launcefton* canal.

Tamar River. The general direction of this river is nearly north by a crooked courfe of about 6 miles, between the counties of Devon and Cornwall; the tide flows through its whole length; Beer-Afhton is a confiderable town near this navigation; which is ufed for the import of coals, fea-fand, lime, &c. and the export of flate and agricultural products. It commences in *Hamoaze* and terminates in the *Tamar Manure* navigation and *Taviftock* canal, at Morwellham quay near Calftock. In the year 1774, an act paffed for the *Bude and Launcefton* canal intended to connect with this at Callftock, but it was never carried into execution.

Tarbeth Canal. In 1773, Mr. *Watt* furveyed the ifthmus between Eaft and Weft *Tarbeth* lochs, on the weft coaft of Scotland, for a canal to communicate between Loch *Fine* and the found of *Jura*; the diftance of high-water mark in the two lochs he found to be 1 mile, and the height of the ridge between them, 45 feet above high-water at neap tides. Mr. Watt's different eftimates were, for a canal with locks 7 feet deep, 17,988l.; and for one 10 feet deep and a proportional width, 23,884l. The expences of a thorough cut without locks, of 12 feet deep at high-water, 73,849l., and for one of 15 feet deep, 120,789l. A very large canal has fince been formed about 13 miles north of this, called the *Crinan* canal, which more effectually anfwers the purpofe of communication between Loch *Fine* and the found of *Jura*.

Tavistock Canal. Act 43 Geo. III.—The general direction of this canal is N.E. for about $4\frac{1}{2}$ miles in the county of Devon; great part of it is confiderably elevated above the level of the fea: its objects are the export of flate, copper-ore, and other minerals, and of agricultural products; the import of coals, lime, and other articles for the fupply of Taviftock town and the furrounding country; and to facilitate the working of the mines in Morwellham down: this canal commences in the tide-way in *Tamar* river (near the commencement of the *Tamar Manure* navigation) at Morwellham quay new bafon, near Callftock, and terminates at the town of Taviftock. From Crebar near the north end of the tunnel, it has a branch of 2 miles to the flate quarries at Mill-hill bridge. From the *Tamar* river, $\frac{1}{4}$ of a mile is level with high water at Morwellham quay; thence in $\frac{1}{4}$ of a mile, is a rife of 237 feet; thence, about $3\frac{1}{2}$ miles to Taviftock is level; the branch is level to New Quarry, about $1\frac{5}{8}$ miles; thence to Mill-hill bridge, $\frac{3}{8}$ of a mile, is a rife of $19\frac{1}{2}$ feet. The locks upon this canal are to be calculated in length and width for the ufe of boats of $12\frac{1}{2}$ feet long, and 5 feet wide, either fingly or feveral together, as on the *Tamar Manure* navigation above mentioned: but the company have the power to erect inclined-planes for boats, or boxes of goods, inftead of locks, if they think fit. Through Morwellham down, which is of hard rock, and fuppofed to be interfected by feveral fiffures, or loads filled with metallic ores, is to be a tunnel about 2500 yards long, and about 460 feet beneath the higheft point of the down in its courfe: near Crebar is to be an embankment and aqueduct bridge 60 feet high, acrofs the Lumbourn river; which is to have a new courfe cut for it for a confiderable diftance near the branch of this canal below New Quarry. This canal is to be fed from the Tavy river at Taviftock, and by any fprings or ftreams within 5000 yards of the line. Mr. *John Taylor* is the engineer to this canal and tunnel, which paffes entirely through the eftate of the *duke of Bedford*, who has leafed to this company the mines which may be found in the tunnelling, or within certain diftances of this canal. In February laft

(1805) about 300 yards in length of the tunnel had been cut, and a known load of copper-ore had been interfected therein, which gave the beft hopes of difcovering other unknown ones, as the work proceeds. This company is authorifed to raife 50,000l., and the amount of each fhare is 50l. The rates of tonnage are for lime-ftone conveyed through the tunnel, 1s. 3d. per ton; for building-ftone, flates, bricks, tiles, clay, fand, earth, dung, ores, iron, and metals (made marketable) conveyed through the tunnel, 2s. per ton; and for coals, coke, culm, lime, timber, bark, corn, grain, and all other goods paffing through the tunnel, 3s. per ton; building-ftone, flate, &c. as above, carried on the whole, or any part of this canal, or its branches, except in the tunnel, 1s per ton; and coals, coke, &c. 1s. 6d. per ton. The laft rates are not to be charged on any goods either carried or fubfequently removed on any part of this canal, which have before paid the tunnel rates: and ores may be carried to the dreffing-floors, or the wafte or rubbifh of mines or loads be removed to proper places on any part of this canal or its branches, free of tolls. Befides the above rates, all goods which pafs into, or from the *Tamar* river, and are not loaded at Morwellham quay, are to pay as follows for reimburfing the owner and occupiers thereof, for the lofs of wharfage on fuch goods, viz. flate 3d. per ton, lime-ftone 6d. per ton; ores, (made marketable) iron, bricks, tiles, clay, fand, earth, and dung, 6d.; and all other goods 1s. per ton; and over and above this, one penny per ton is to be paid on all goods entering the canal bafon at Morwellham. The *duke of Bedford* may make collateral branches or rail-ways to this canal in any part.

Tavy River. The general direction of this river is N.E. for about $2\frac{3}{4}$ miles in the county of Devon; the tide from the fouth coaft flows through its whole length: its objects are the import of coals, fea-fand, &c. and the export of flate, copper-ore, &c. It commences in *Hamoaze* and terminates at Lophill quay.

Taw River. The direction of this river, or eftuary, is nearly eaft for about 8 miles on the north-weft coaft of Devonfhire: the tide flows through its whole length: its objects are the fupply of Barnftaple and the adjacent country with coals and other articles, and the export of farming products. This navigation commences in St. George's Channel, at Biddeford bay, and terminates at the town of Barnftaple: near to Appledore the *Torridge* river joins this navigation.

Tay River. The general direction of this river, firth, or eftuary, is nearly weft for about 26 miles, between Angus and Fife, and in the county of Perth in Scotland. The tide flows through its whole length: its objects are the fupply and trade of Dundee and Perth, and the adjacent country. Dundee is the 18th Britifh town, with 26,084 perfons, and Perth the 26th, with 14,878 perfons. This firth commences in the German Ocean, and terminates at Perth bridge. This bridge, built of ftone by Mr. *John Mylne*, was fwept away by a rapid flood in 1621. In 1763, Mr. *John Smeaton* was confulted on the building of a new bridge; and in 1766 he began one of 7 arches, where the river was 893 feet wide: the depth of the Tay at this bridge at neap tides in dry feafons was only 2 feet, at fpring tides 10 feet deep. At Stanley, 7 or 8 miles higher up this river, three foughs or tunnels of confiderable length (one of them from 12 to 9 feet wide arched with ftone) are driven through the hill, which occafions a great loop in the river, by which 24 to 20 feet fall is gained, for a large portion of the ftream, to work cotton-mills and other machinery; and running in this fubterraneous channel it never freezes.

Tees River. The general direction of this river is nearly S. E. by a crooked courfe of about 12 miles, between the counties of York and Durham: the firft four miles are by a very wide eftuary: the tide flows through its whole length: its objects are the trade of Stockton, and the export of agricultural products. Stockton is a confiderable town on this river; which commences in the German ocean, at Seaton Nook, and extends to the town of Stockton. In the prefent autumn there was an intention of improving this navigation. In 1803, the foundations were laid for an iron-bridge, to be erected under the direction of Mr. *Thomas Wilfon*, over this river at Yarm, a few miles above Stockton, in place of an old ftone bridge, whofe clumfy piers had long obftructed the current, and occafioned the river frequently to overflow its banks. In 1768, the *Winfton and Stockton* canal was propofed for extending this navigation weftward to the coal diftrict about Winfton.

Teign River. The direction of this river, or eftuary, is weft for about $4\frac{1}{2}$ miles in the fouth-eaftern coaft of Devonfhire: the tide flows through its whole length: its objects are the import of Newcaftle or Welfh coals, and the export of potters' clay, bovey-coal, and agricultural products: it commences in the Englifh channel, and terminates at Newton-Abbots, at the commencement of the *Stover* canal, near to Newton-Bufhel.

Ternbridge and Winsford. In 1765, Mr. *Whitworth* propofed a canal from the *Severn* river at Ternbridge below Shrewfbury, to the *Weaver* navigation at Winsford, $63\frac{1}{2}$ miles, in the counties of Salop, Stafford, and Chefter, with a branch therefrom, near Bridgeford; 43 miles, to the *Trent* river at Wilden-Ferry. From the *Severn* to the fummit or grand-ridge (requiring 25 feet deep cutting,) below Offley-Park, 24 miles, is a rife of $136\frac{1}{2}$ feet; thence to the Trent branch, ($1\frac{1}{4}$ mile below Bridgeford,) $7\frac{1}{4}$ miles, is a fall of $54\frac{3}{4}$ feet; thence to the fummit or grand-ridge again, (requiring 25 feet deep-cutting,) in Madeley park, $10\frac{1}{2}$ miles, is a rife of $800\frac{1}{2}$ feet; thence to the *Weaver* navigation, $22\frac{1}{4}$ miles, is a fall of 284 feet: the branch from Bridgeford to the Trent has a fall of $209\frac{1}{2}$ feet. The courfe of this canal is by Wansford, Allfcot, Crudgington, Chetwin-park, Batchacre-Grange, Ecclefhall, Standon, Wyburnbury, and Barton-crofs, near Nantwich. The branch is conducted by Stafford, Tixall, and thence following within a fmall diftance the courfe of the Trent river. This canal was propofed to be 27 feet wide at top, 18 at bottom, and 5 feet deep, with a towing path on both fides; the locks 60 feet long and 13 wide, and about 10 feet rife each: the boats of 50 tons burthen: 78 road bridges, and 25 accommodation bridges were thought neceffary, and 162 aqueducts and culverts: the eftimated expence was 99,800l. The *Staffordfhire and Worcefterfhire* and the *Trent and Merfey* canals, which were adopted in the following year, embrace all the general objects of this canal. The *Sandbach*, and the *Newport and Stone*, have fince been propofed to occupy parts of the fouth-weftern end of this line, but, like this, were over-ruled.

Thames River, (*lower part*). Acts 19. 29, 39, 42, 43, 44, and 45 of Geo. III.—This fine river, by far the moft important for trade, not only in Britain but in the whole world, has its career nearly weft for about 72 miles between the counties of Kent and Effex, and Surry and Middlefex. The firft 20 miles is by an exceeding wide eftuary; the next 21 miles is ftill an eftuary of confiderable width; the remaining 31 miles is crooked, and gradually diminifhing: the tide flows very powerfully through its whole length. To enumerate its objects would be to recount almoft every fpecies of trade and commerce which is carried on in

Europe. At East Mersey it connects with the *Colne* river; at West Mersey, with *Blackwater* river; at Foulness east point, with *Crouch* river; at Whitstable and at Sheerness, with the *Medway* river; at Gravesend, with the *Thames and Medway* canal; opposite to Purfleet, with the *Darent* river, or Dartford creek; at Bow-Creek, with the *Lea* river; at Blackwall and at Limehouse-hole, with the *Isle of Dogs canal*, (a new side-cut for shortening the navigation of this river); at Greenland-dock, and at Wilkinson's gun wharf, Rotherhithe, with the *Grand Surry* canal; and, at Limehouse, with the *Limehouse* canal. London, the first British town, has a population of 864,845 persons; Greenwich is the 31st, with 14,339 persons; and Woolwich is the 53d, with 9,826 persons; Margate, Feversham, Milton, Queenborough, Sheerness, Leigh, Gravesend, Grays-Thurrock, and Deptford, are also considerable towns on or near this lower part of the *Thames* river; which commences in the English channel at East Ness near Margate, and terminates in the *Thames*, middle part, at London-bridge. Large ships of war can come up to Deptford, and merchants' ships of 7 to 800 tons burthen frequently lie at the keys close to London-bridge. The port of London, or part wherein the ships lie, generally called the pool, extends almost 4 miles, nearly to Deptford, in which space more than 1000 vessels have been seen moored at one time! the rapidly increasing trade of this grand emporium of commerce, the regulations which have of late been made, for mooring the ships at more convenient distances, for a passage up and down the river, and the contiguity of the *West India* and *East India* docks to Blackwall are expected ere long, to extend the tiers of ships as far as that place. It was stated, in the year 1800, that the trade of the port of London had increased in the last, or 18th century, by 6547 vessels and 1,327,763 tons annually; and that (including repeated voyages,) 13,144 ships and vessels were then employed in this trade, to foreign countries, the colonies, and coastwise, besides 2288 lighters, barges, and punts, employed in the middle part of the *Thames*, and on the *Lea* river, and 3336 of the like kinds of vessels used below bridge, in the lading and discharging of vessels, together with 83 boats, sloops, cutters, and hoys, 3000 watermen's wherries, 155 bum-boats, and 194 peter-boats, the total number, (exclusive of ships of war, transports, and navy and victualling and ordnance hoys,) being 22,500 vessels of various sizes and dimensions, either trading to, or stationed within the pool or port of London; the total value of the goods imported and exported annually by them exceeding 67,000,000l.! The corporation of the city of London, as conservators of the river *Thames*, and under the special authority of the above acts, are, at this time, carrying on considerable works for the improvement of this river: several mooring chains in the pool have been purchased of lord Guydir and others, and a harbour-master, approved by the Trinity-house, is appointed to regulate the mooring and conduct of vessels, agreeable to the 19, 29, and 39 of Geo. III.: one of the largest canals ever attempted has been cut, near 1¼ mile in length, 142 feet wide at top, and 24 feet deep! across the *Isle of Dogs*, for shortening the passage of vessels to and from the pool, and to avoid the long circuit by Greenwich and Deptford; Mr. *William Jessop* is the engineer, under whom the locks and other works of this canal were successfully conducted and nearly finished, when an unforeseen accident, by the blowing up of the coffer and preventer dams, just as the entrance locks were completed, on the 24th of July last, (1805) prevented this canal from being opened until the 9th of December, when the Duchess of York, West Indiaman, of 500 tons burthen, passed through the same, in presence of the lord mayor and corporation of London. Several large sums of public money have been granted by the above acts out of the consolidated fund; for the repayment of which vessels passing through this canal of 200 tons or upwards are to pay 2d. per ton; those from 200 to 100 tons, 1½d. per ton; from 100 to 50 tons, 1d. per ton; 50 to 20 tons, 5s. each, and boats and craft 1s. each. Two or more piers are intended to be built at the entrance, for facilitating the entrance of vessels to this canal. Between this canal and the entrance of the *East India* docks, there is a large mass of silicious pudding-stone, consisting of chert pebbles imbedded in a very hard cement, which lies in the bed of the river, and has proved fatal to several ships, on which account the committee, in September 1802, and on several other occasions, advertised for persons who would undertake to lower this rock 18 feet, its length being about 40, and breadth 30 feet; the newspaper accounts of the Boddington West Indiaman having struck on this rock on the 12th of September last appear to be incorrect, the rock being now surrounded by piles and booms, so that no ship can approach it. In the year 1773, Mr. *James Sharp* suggested the propriety of floating, or wet-docks, for the loading and unloading of ships in the Isle of Dogs; after much discussion a plan was adopted for this purpose, in the year 1799, called the *West India Docks*, and Mr. *William Jessop* and Mr. *Ralph Walker* were employed as engineers. On the 12th of July 1800, the first stone of this great undertaking was laid with much ceremony. On the 22d July 1802, an unfortunate accident occurred by the bursting of the coffer-dam at the entrance at Blackwall, but which did not prevent the great or import dock, from being opened for the use of West-India ships on the 3d of September 1802. This fine dock, the largest in Britain, is 2600 feet long, 510 feet wide, covering more than 30 acres of ground; its depth being 29 feet, and it is walled in the most substantial manner with bricks, and coped with immense blocks of stone. Three stacks of the superb warehouses on the banks of this dock were completed at this time: on the 22d of August 1803, several other warehouses on the N. side of the dock were finished, and declared ready for public use; and, on 5th July last, two warehouses on the south side, and the whole of that quay were completed. The outward-bound dock, 2600 feet long, 400 feet wide, and 29 feet deep, has been rapidly proceeding since the completion of the great dock, and is now almost ready, we believe, for opening. At Blackwall, and at Limehouse-hole, there are spacious entrance basons, connecting by tide-locks with the *Thames* river; from these entrance basons there are locks into the outward and inward, or export and import docks: these docks are calculated for the accommodation of 300 ships, 12 of which can conveniently enter or go out in one tide: there are to be six immense ranges of warehouses in the whole, with cellars, cranes, and every possible convenience: the whole is to be surrounded with a wall 30 feet high, and a wet foss 12 feet broad, and 6 deep: for security from fire, no dwelling-houses or work-shops are to be built within or near to the boundary wall; no gunpowder is to be suffered to enter the walls, or any fire, candles, or lamps to be lighted within the same, except the necessary street-lamps on the quays. The company were at first authorized to raise 600,000l. the amount of shares being 500l. each, which, in 1802, bore a premium of 28l. per cent.: the profits to the subscribers are limited to 10 per cent.: several loans of the public money from the consolidated fund have been made towards completing this design. Mooring-chains are provided in the river opposite the entrance basons, for the use of ships entering these docks, in which all West India goods whatever (except tobacco in some cases,) are to

be landed, and all outward-bound ſhips for the Weſt-Indies are to load herein, or in the *Thames* at Blackwall; but the tonnage for the building and maintenance of theſe docks is, (by 39 Geo. III.) not levied excluſively on the Weſt India trade, as every veſſel both on its inward and outward voyage (except coaſting veſſels under 45 tons, king's ſhips, corn, fiſhing, and paſſenger veſſels, and craft navigating above Graveſend,) is to pay: coaſting veſſels at the rate of 1d. per regiſter ton; and ſhips trading to parts beyond the ſeas are to pay higher rates, amounting, in ſome caſes, to 3½d per ton; ſee the particulars, as alſo the rates for wharfage, warehouſe-room, cooperage, &c. in the *Agricultural Magazine*, vol. i. p. 115. Mr. *Robert Edington*, in his *Eſſay on the Coal Trade*, 1803, after eſtimating 4284 coal-ſhips to enter the port of London annually from the neighbourhood of Newcaſtle-upon-Tyne, with 1071 chaldrons each, on the average, (a quantity conſiderably ſhort of the actual importation, ſee *Monthly Magazine*, vol. xvii. p. 99, and vol. xix. p. 99.) objects ſtrongly to the above rate, which annually taxes the coals conſumed in London and its vicinity with 4284l., on account of theſe docks, which they are not allowed to enter. For the general accommodation of ſhips unloading and loading in the port of London, another ſet of docks was, after much diſcuſſion, undertaken, in the year following, called the *London Docks*, (or ſometimes the Wapping Docks,) Acts 40, 44, and 45 of Geo. III. Mr. *John Rennie* and Mr. *Alexander* were the engineers employed; on the 26th of June 1802, the firſt ſtone of theſe works was laid, by Mr. Addington, the then miniſter; and the ſame proceeded without any diſaſter or impediment, until the great dock, the entrance baſon, and ſeveral of the warehouſes were completed, and opened for uſe on the 1ſt of February laſt (1805). The great dock is about 1260 feet long, and 830 feet wide, and covers about 24 acres of ſurface: it is 29 feet deep from the top of the walls; but the depth of water is only 23 feet; the walls are of brick, coped with ſtone, and every part of the work is executed in the moſt complete and maſterly ſtile. On the northern ſide of the dock there is an open ſhed the whole length, for examining and weighing and the landing of goods, under cover from the weather, from whence a number of ſmall trucks moving on rail-ways convey them to five immenſe ſtacks of warehouſes behind them, or the cranes hoiſt them into carts, as may be wanted. Near the S. E. corner of this dock are two immenſe warehouſes let to government for the ſtowage of tobacco; one of them is 762 feet long, and 160 wide, the other 250 feet long, and 200 feet wide, each being in one ſingle room, without any partitions, and their roofs are ſaid to exceed 6 acres of ſlating; they are but one ſtory high, but have ſpacious arched vaults under them of the ſame extent, for the ſtowage of wine, oil, ſpirits, &c. Other large ranges of warehouſes are to be built, and their fronts have been begun north of the preſent range of warehouſes; the windows and doors of theſe laſt being bricked up, ſerve as a temporary wall to encloſe the premiſes: warehouſes are alſo intended on the weſt and ſouth ſide, where the high temporary fence-wall at preſent ſtands. The only entrance at preſent to this dock, from the *Thames*, is near to Bell-dock in Wapping, where two maſſive piers of ſtone project into the river, and have a tide-lock between them, and further north is a curious iron double ſwing-bridge, in the line of Wapping-ſtreet, which we have already deſcribed; within this is the entrance baſon, of an irregular figure, of about 3 acres extent: this baſon is connected with the river at every high-water, by the opening of the gates, which ſhut again and retain the water at that height; from this baſon ſhips lock up into the great dock, whoſe ſurface is kept about 3 feet above the height of ordinary tides, by a powerful ſteam-engine erected on the eaſt ſide of the entrance baſon for that purpoſe, and the bottom of the dock is about 15 inches above low-water mark in the river. There is deſigned to be another entrance from the *Thames* by means of Hermitage-dock, into the great dock at its S.W. corner; and from near the oppoſite or N.E. corner, proviſion has been made, and the connecting canal formed, which is to join it with another large dock, intended to be dug, and connect with the *Thames* at Shadwell. Notices were given in September laſt of an application to parliament for further powers, to proceed with the above works. The preſent dock is capable of accommodating 200 merchant ſhips, and the entrance baſon will hold a vaſt number of ſmall craft, without impeding the paſſage of ſhips to or from the great dock. The whole of the docks or warehouſes are, when completed, to be ſurrounded by a very high wall to prevent depredations or the communication of fire, againſt the happening of which the ſame regulations are adopted as at the Weſt-India dock above mentioned. Six large mooring chains are fixed at proper diſtances from each other in the great dock for ſhips to moor to, conſiſting of very large floating blocks of deal timber. This company were authoriſed by their firſt act to raiſe 1,500,000l., the amount of each ſhare being 500l. They were required to purchaſe the concern of the Shadwell water-works for 50,000l.; and ample proviſions are made for compenſating the owners of the river-quays, the proprietors of ſtreet-cart licences, &c.: and full accounts of the receipts and expenditure of this company, and of the Weſt-India dock company, are to be preſented annually to parliament. The tolls or rates payable to this company, by ſhips which enter their docks, are for Britiſh coaſting veſſels (including colliers) 1s. per ton; five other claſſes of ſhips are enumerated, which are to pay from 15d. to 30d. per ton; ſee *Agricultural Magazine*, vol. iii. p. 162. For the landing, loading, and houſing, and for ſhipping of goods of every different kind, the ſame ſums reſpectively are to be taken by this company, as were uſually paid at the different quays of the port of London in the year 1798. The whole of the ſcite of theſe docks was covered either with ſtreets and houſes, or with gardens, and which the company had to purchaſe for immenſe ſums of money. For the particular accommodation of the large ſhips belonging to the Eaſt-India company, a third ſpacious ſet of docks has been deſigned, and in the 43 of Geo. III. an act paſſed for enabling the company to raiſe 200,000l. for the purpoſe of building the *Eaſt-India Docks*; and to purchaſe the dock belonging to Mr. Perry's maſt-houſe at Blackwall, for their entrance baſon. Mr. *Ralph Walker* is the engineer; and on the 4th of March laſt (1805) the firſt ſtone of this great undertaking was laid by captain Joſeph Huddart, and the works are now proceeding with the utmoſt expedition: the largeſt, or import dock, is to cover 18 acres of ground, the export dock is to be 9 acres in content, and the entrance baſon about 3 acres: the depth of theſe docks is to be greater than either the *London* or the *Weſt-India* docks; the entrance locks now building are 48 feet wide in the clear, and each gate is to be 27 feet wide. Near to Deptford, *Greenland-Dock* has its entrance, by a tide-lock, into the river *Thames*; this dock is about 900 feet long and 400 feet wide, and was conſtructed ſeveral years ago, for the accommodation of ſhips employed in the Greenland, or whale fiſhery, with ſuitable conveniences at proper diſtances for melting and refining their oil. It is intended that the *Grand Surry* canal ſhall have a cut into, and a paſſage for its barges, through this dock: and the ſame company are now excavating a dock near the termination of their canal, at Wilkinſon's gun-wharf, Rotherhithe,

which feems to be intended to admit fmall fhips from the *Thames*. At Deptford, Woolwich, and at Sheernefs there are fpacious dock-yards and naval arfenals on the banks of this river, and others at Chatham, within a few miles of it, on the *Medway* river. In the year 1800 it was propofed to make a large dock and yard, for repairing fecond and third rate fhips of war, of which *Major General Bantam* has the direction, near the falt pans on the *Ifle of Grain*, on the *Medway* fide of it: it principal object is for repairing the fhips ftationed in the Downs and North Seas. In the year 1804 it was propofed to form a wet-dock, of about 12 acres extent, connecting with the *Thames* river, by *Northfleet* creek near Gravefend: the fcite of the old chalk pits is intended to be excavated for this dock, in which the new fhips of war built at Deptford, Woolwich, and Chatham are to be received to be rigged and fitted for fea, inftead of fending them to Sheernefs; that the arfenal there may be wholly appropriated to the victualling and ordnance department. A pier is now building for the protection of *Sheernefs* harbour, under the authorities of the acts of 41 and 42 of Geo. III. At Margate, there was an ancient wooden pier in this river, for the protection of the hoys and veffels trading to that place, but in 27 Geo. III. an act paffed for an excellent ftone pier, which has fince been there erected. The great diftance which the inhabitants of Gravefend, and Grays-Thurrock, and all thofe parts, have to travel (over London bridge) to communicate with each other by land, gave rife, in May 1798, to the propofition by Mr. *Ralph Dodd* for a tunnel, or road arch, under the *Thames*, from near Gravefend to Tilbury Fort (fee Nicholfon's Journal, 4to. vol. ii. p. 473); and an act of 49 Geo. III. paffed to authorife the raifing of 50,000l., in 100l. fhares, for the *Thames Tunnel*, and to levy 2s. 6d. on each coach, 4s. on each waggon, 2s. on each cart, 1s. on each horfe, 2d. on each foot-paffenger, and fome other tolls, for paffing through this tunnel. Government to pay 100l. annually, in lieu of all tolls, for the paffage of troops and of government ftores of every kind: 80l. to be paid annually to his majefty, and 30l. to the corporation of Gravefend and Milton, in lieu of the right of ferries, near the intended tunnel, to which they are entitled. Mr. *Dodd* propofed his arch to be a cylinder of 16 feet diameter in the clear, and eftimated that the fame might be executed for 16,000l., the length of the tunnel being 900 yards; but it does not appear that at this time, or for more than two years after, any borings had been made, even on the fhore of the river where the tunnel was intended, to prove whether the chalk rock, which Mr. *D.* had calculated upon tunnelling in, exifted or not: at length, about September 1800, a bed of chalk, *fuppofed* to be the fame which appears on the furface at Gravefend, was difcovered, by Mr. *D.*'s borings, at 72 feet beneath the furface, at Tilbury Fort; a fteam-engine was thereupon erected, and a perpendicular fhaft of 146 feet deep was funk at Gravefend, all in chalk; when, by one of thofe *unaccountable accidents* to which abortive fchemes feem peculiarly liable, this engine-houfe took fire, and was burnt down, and fhortly after the fcheme was given up altogether. In the laft feffion of parliament (45 Geo. III.) an act paffed for making other archways under the *Thames*, for the paffage of carriages and foot paffengers, between Rotherhithe and Limehoufe; and we have fince read that Mr. *Robert Vazie* is the engineer to thefe *Rotherhithe archways*, that the footway arch is to be made a little to the weft of the *London-Dock* entrance, and the carriage-way arch at the ancient horfe-ferry between Limehoufe and Rotherhithe. On inquiry, we have been told, that the prefent fcheme is, to fink a fhaft on one fhore of the *Thames*, with an engine thereon and pumps, and to continue the fame to a fufficient depth, at which to begin the tunnel in oppofite directions, rifing to the oppofite fhore of the river one way, and to a point fufficiently inland the other way, for a regular and proper afcent for carriages. We can hardly fuppofe that this matter has proceeded thus far, without its being afcertained, by a feries of borings, quite acrofs the river, at fhort diftances from each other, that there is no fiffure or crack in the clay, beneath the alluvial matters, which may be filled up with quickfand or other loofe foil impracticable to tunnel through, under the bed of a river: but, if we admit the whole matter to be folid clay under the water-way or bed of the river, yet the number of houfes which muft be pulled down, or endangered, oppofite to the tunnel, in this way of conducting the bufinefs, in order to bring the archway to the furface on one fide of the river, and the inconvenient diftance which that entrance will be from the water-fide, are almoft infuperable objections to its adoption. We have no doubt of the practicability of forming as many arch-ways under the *Thames* as may be wanted (if money is not fpared, and fcientific and proper men are employed on the work), but are of opinion that for fuch to fucceed, the river muft be piled off for fhort lengths at a time, while the neceffary excavation is made in the bottom for turning a length of the arch, and fecurely covering it with clay or puddle: and after feveral fucceffive lengths are thus formed, the water and traffic of the river may be admitted over the part which is completed. Very powerful pumping-engines will be neceffary, in this or any other way of conducting fuch a work with the probability of fuccefs. The *Thames* river, below London, is embanked through a great part of its courfe; the time when thefe banks were firft erected is uncertain, but they appear to be of great antiquity; and during feveral hours of each tide, the adjoining meadows are 10 feet or more below the level of the water. At Dagenham, about 7 miles below Blackwall, a large breach in one of thefe banks happened, which captain *John Perry* fucceeded in ftopping, after feveral others had failed in their attempts. On the 5th of Auguft 1776 the plan was firft adopted of employing *convicts* in ballafting, and other works for the improvement of the river *Thames*, under Mr. *Duncan Campbell*; thefe men, properly ironed, are lodged in hulks, or old veffels, off Woolwich, and have principally been employed in enlarging the wharfs at Woolwich Warren, or Royal Arfenal, which work is ftill proceeding. In the year 1785, and again in 1802, the *London Lynn and Norwich* (or North London) canal was propofed to join the *Thames* river at Limehoufe. In 1798 a new channel was propofed to be cut for the *Thames* river ftraight acrofs the Ifle of Dogs, and dams with fluices and locks to be made on the old courfe of the river, for converting the fame, round the ifland by Deptford and Greenwich, into one vaft floating dock for fhips! About the fame time, the *London Docks* were in contemplation, and a canal was propofed to extend from them to the *Thames* river at Blackwall; the *Ifle of Dogs* canal has fince been made, and in part anfwered both thefe purpofes. In 1802 the *Canterbury and St. Nicholas-Bay* canal was propofed to join the *Thames* at the latter place; and in the fame year the *London and Waltham-Abbey* canal was intended to join at Bell-wharf in Shadwell. The *Thames and Medway* proprietors pay 1s. annually as an acknowledgment to the city of London, as confervators of the *Thames* river, for the liberty of connecting therewith.

THAMES RIVER (*middle part*). Acts 14 and 17 Geo. III. —The general direction of this part of the Thames river is nearly weft, by a very crooked courfe of 37 miles between the counties of Surrey and Middlefex; the tide flows through the firft 16½ miles thereof to Richmond bridge: its objects are the fupply of London, and the immenfe trade which is carried

on with the rivers and canals westward: at Vauxhall creek it is joined by the *Grand Surry* canal; at Wandsworth entrance-bason, the *Surry Iron Rail-way* joins; at Brentford Creek the *Grand Junction* canal joins, and at Ham Haw, near Shepperton, the *Wey* river joins (2 miles from the junction with the *Basingstoke* canal). London, the first British town, has 864,845 persons; Wandsworth, Brentford, Kingston, Chertsey, and Staines are also considerable towns on this part of the *Thames* navigation; which commences in the *Thames* lower part at London bridge, and terminates in the *Thames and Isis* navigation at London stone, at the extremity of Middlesex county, about ½ a mile above Staines bridge; from near Chelsea, Pimlico creek extends for about ¾ of a mile to Chelsea water-works engine. From low-water at Richmond bridge to London-stone, 20½ miles, is a rise of 36 feet; see a section thereof in *Gentleman's Mag. March*, 1771, and in *Zachary Allnutt's Considerations on the Thames River*, 1805, wherein it appears, that the navigation hereon is in two or three places interrupted by shallows, not exceeding 2 feet 9 inches depth of water in ordinary times. At Laleham, Mr. *John Rennie* gauged the stream of this river, in the dry season of 1794, and found 1155 cubic feet of water per second to be then passing down. The corporation of the city of London, as conservators of the river *Thames*, and by the 17 of Geo. III. above, were unauthorised to make any new side-cut by this part of the river, or to erect any weir quite across the channel of the river; and their exertions for the improvement of this navigation, so much in need of amendment, have been confined to the erecting of jetties and weir-hedges, for contracting the breadth of the stream in many of the shallow places, to the dredging or ballasting of others, to deepen the channel, and to the establishing of regular flushes of water, twice a week, or oftener, from the pounds and mill-dams in the upper part of the river, for enabling barges, during the run of such flushes, to pass the shallow places; except, that they have completed a good horse towing-path through the whole length of this navigation, beginning at Putney bridge, on the south shore of the river: immense sums of money (upwards of 1400*l.* per annum) having been expended on the above inefficient measures, and yet the navigation in all dry seasons continues intolerably bad, and also frequently interrupted and rendered dangerous by floods. We are happy to observe, that notices were given in September last (1805) for an act to authorise the making of weirs across the river, and side-cuts and locks, in the parishes of Laleham, Littleton, Shepperton, Sunbury, Chertsey, and Thorpe. The above act (17 Geo. III.) authorised the city of London to purchase certain local tolls on the navigation between Staines and Richmond, and to levy 4d. per ton per voyage up and down, for the above purposes; they have a commodious barge stationed on the river for the residence of a collector of this toll, and an annual account of all the receipts and disbursements under this act is presented to parliament. The *Grand Surry* canal was (by its act 41 Geo. III.) required to pay 2 guineas as a fine, and a rent of 60l. annually, for the liberty of connecting with this navigation; and the *Croydon* canal 40l. per annum; the *Surry Iron Rail-way* is to pay 10l. per annum; and the *Grand Junction* company are to pay 600l. per annum, and a toll of ½d. per ton on all goods which pass into or out of this canal. Among the bridges upon this navigation, *London Bridge*, at its commencement, built of stone in 1209, comes first to be noticed: the river at this place is about 900 feet wide, the bridge, which is 60 feet high and 74 feet wide, consists of 19 arches, the middle one of which is 72 feet wide, but the next thereto on each side are narrow ones, and no regular order is to be observed in the arrangement of the arches, which are most of them of different widths, under 20 feet; the piers between them are immensely thick, being also surrounded with starlings or vast frames of piling and cross beams of timber, intended for the protection of the foundations of the bridge: previous to the making of the large lock or centre arch, in 1756 (by the removing of a pier and its starling, and turning one large arch instead of two) the clear water-way between all the starlings amounted but to 194 feet, and above the starlings (which are covered when the tide has risen about two thirds of its usual height) the water-way amounted to only 450 feet, or half the width of the river: a further obstruction also arises from the water-wheels, which are fixed on the upper side of the bridge at both of its ends, opposite to several of the arches, for pumping up water for the supply of the city of London and Borough of Southwark. By these contractions of the water-way, a fall and current is occasioned under this bridge, which for several hours of each tide is quite tremendous, and proves a most serious obstacle to navigation, as well of danger to the bridge itself. If Mr. *John Smeaton*'s advice had not been quickly followed, in 1756, in returning and throwing in the stones, which had been recently taken up from the old middle pier, together with many cargoes of other large and rough stones, the adjoining starlings and piers of the great lock would certainly have been undermined, and the bridge have fallen: great quantities of chalk and Kentish rag-stones are now annually brought and deposited within the piling of the starlings, and between them, at the time they are repaired; a work for ever requiring to be done, in some part or other, of these clumsy obstructions to the waters and to navigation: immensely deep gulphs are formed at each side of the bridge by the pitch or fall of the water, and the soil and rubbish excavated therefrom is continually thrown up at a distance, so as to form large banks dry at low-water, in spite of a continual dredging or ballast-heaving, which is resorted to for removing them. These inconveniences, which had been long and loudly complained of, occasioned, about the year 1799, a proposal, for pulling down this bridge, and substituting two stone bridges, with capacious arches: these were to be placed near to each other and to connect at their ends; the centre arch of each was to have a draw-bridge, for admitting ships up the river, as far as Blackfriars bridge; the intention of the two bridges being, that one of the drawbridges might always be shut down for the passage of carriages and persons, while ships might be passing through the other into or out of the bason between the bridges. Another proposal was, to construct a cast-iron bridge of one single arch of 600 feet span and with 65 feet clear opening above high water; as we have already mentioned: these, and other projects for the same purpose were minutely and carefully examined by a select committee of the house of commons, and their reports, together with views of the different proposed bridges, have been since published, and a proposal made for a cast-iron bridge of three arches, resting on stone piers, the centre arch 65 feet high for the passage of ships; in September 1802, the city of London gave notices of their intention to apply for an act of parliament for removing London bridge and building another, but nothing further, we believe, has since been done. *Blackfriars Bridge* is an elegant stone structure, offering scarcely the least impediment to the navigation; it was built in 1770, by Mr. *Robert Milne*; the river in this place is 995 feet wide, it has 9 large elliptical arches, the centre one 100 feet wide, the others regularly diminishing to the outside ones which are 70 feet each. The whole cost of this bridge, in the 10¾ years during which it was in hand, was 150,840*l.* *Westminster Bridge* was built of stone in the year 1750; the river in this

place is 1220 feet wide; there are 17 large, and two ſmall ſemi-circular arches in this bridge, the centre one 76 feet wide, the others diminiſhing by 4 feet each in width, to the ſmall ones at the ſides; the coſt of this bridge and its avenues was 389,500l., and it was about 10 years in hand. At Batterſea and at Putney there are narrow, low, and inconvenient wooden bridges over this fine river. On the 4th of June 1783, a handſome and convenient ſtone bridge was begun over this river at Kew, and in the year 1774, another ſtone bridge was begun at Richmond. About the year 1801, a new ſtone bridge was built over this river at Staines, but it was ſhortly after obliged to be taken down, owing to a ſettlement therein; an iron bridge was next ſubſtituted, and opened on the 3d of September, 1803, of one arch, with 180 feet ſpan, riſing only 16 feet above the ſtone abutments on which it reſted; but this, we are ſorry to add, has lately ſuffered the fate of the other, and has neceſſarily been taken down, a circumſtance the more to be regretted, as this was the firſt caſt-iron bridge brought into uſe in this part of the kingdom. At Walton, there is a curious bridge, conſiſting of a large wooden opening, and ſmaller brick arches on each ſide of it. It may be proper to add, that the intention has very recently been announced, of building a new ſtone bridge over this river from Vauxhall to Millbank, with a new road over the ſame from Vauxhall turnpike acroſs Tothill fields to Pimlico. In the year 1770, and again in 1794, the *Maidenhead and Iſleworth* canal was propoſed to join this river at Iſleworth and at Bolter's Lock, or Taplow mill; in 1792, the *Hampton Gay and Iſleworth* was propoſed to join at the latter place; in 1801, the *Leatherhead and Thames* rail-way was propoſed to join this river at Weſt Mouleſy, and an extenſion of the Grand Surry canal was intended to Kingſton; in 1802, a cut from the propoſed weſtern branch of the *Grand Junction* canal was propoſed to join at Ham Haw oppoſite to the *Wey* river; and, in 1803, the *Portſmouth and London* rail-way was propoſed, to terminate in Stamford ſtreet, near Blackfriars bridge.

Thames and Isis Navigation. Act 11, 15, 28, and 35 of Geo. III.—The general direction of this navigation is nearly N. W. by a very ſerpentine and crooked courſe of about 110 miles between the counties of Surrey and Berks, and of Bucks, Oxford, and Glouceſter: its weſtern end is conſiderably elevated; its objects are the ſupply of London and the carriage of coals, and a variety of other articles: near Reading it connects with the *Kennet* river; at Abingdon, the *Wilts and Berks* canal joins this navigation: at Badcock's garden in Oxford, this navigation is joined by the *Oxford* canal, and at Godſtow, by the *duke of Marlborough's* cut from the ſame canal. Oxford is the 38th Britiſh town, with a population of 11,694 perſons, and Reading is the 55th, with 9,742 perſons; Staines, Windſor, Maidenhead, Great-Marlow, Henley, Wallingford, Abingdon, and Lechlade, are alſo conſiderable towns on this navigation, which commences in the *Thames* middle part at London-Stone near Staines, and terminates in the *Thames and Severn* canal at Lechlade. From Staines-ſtone to the water above Bolter's Lock, 15½ miles, is a riſe of 34 feet: thence to the entrance of the *Kennet* river 24½ miles, has a riſe of 27½ feet, beſides the riſe at the weirs; thence to the termination to the *Thames* and beginning of the *Iſis* river, is about 23 miles; thence to the *Wilts and Berks* canal about 10 miles; thence to the *Oxford* canal about 8 miles, and thence to Cricklade about 29 miles. The Gentlemen of the counties adjoining this navigation are Commiſſioners for executing, in different diſtricts, the above acts; they have borrowed 60,800l. and have expended the ſame, over and above the ſurplus of the tolls, in making 24 ſide-cuts with opening weirs and pound-locks, with a horſe towing-path, and other works for improving this navigation, which is now accompliſhed, ſo that very long and wide barges drawing 3 feet 10 inches, can in general paſs the ſame; the rate of tonnage is only ¼ per ton per mile; and an account of the receipts and expenditure on this concern is annually preſented to parliament. In 1796, the receipts amounted to 9,839l. in 1801, to 10,060l. in 1802, to 7,173l. Mr. *Zachary Allnutt* is engineer to the 2d and 3d diſtrict of this navigation. In the year 1800, Mr. *Wilſon* prepared a deſign and model for his Majeſty, of a caſt-iron bridge, of one arch, propoſed to be erected over the *Thames* at Datchet. In the year 1770, the *Reading and Maidenhead* canal was propoſed to join this navigation at Sunning, and at Bolter's lock; in 1802, a weſtern branch of the *Grand Junction* canal was propoſed to join this navigation at Harleyford near Great Marlow, and croſſing the ſame at that place, it was to proceed to join it again near Reading; and in the ſame year another branch from the *Grand Junction*, through Ayleſbury, was propoſed to join this navigation near to Abingdon, and to the *Wilts and Berks* canal.

Thames and Avon Canal. In the reign of Charles II., Mr. *Joſeph Moxon* was employed to ſurvey the line for a canal, and a bill was prepared and brought into parliament, from the *Thames and Iſis* navigation at Lechlade, by Cricklade, Malmſbury, Chippenham, and thence by the courſe of the *Avon* river to Bath, 40 miles in length: in 1754, this deſign was again revived, with the idea of employing the ſoldiers upon it; and it was ſtated that a canal 50 feet wide at top, 30 at bottom, and 4 feet deep, might thus be completed for 1000l. per mile.

Thames and Medway Canal. Act 40 and 44 of Geo. III.—The general direction of this canal is S.E. for 8⅓ miles in the county of Kent; it is level with the ordinary high tides in the river Thames: its object is for ſhortening the voyage of barges from Graveſend to Chatham round by the Nore; Chatham is the 46th Britiſh town, with a population of 10,505 perſons, and Rocheſter the 90th, with 6,817 perſons; Graveſend is alſo a conſiderable town near this canal, which commences in the *Thames* river at Graveſend, and terminates in the *Medway* river at Nicholſon's ſhip-yard in Friendſbury, with a cut from Whitewall on the line of this canal to the *Medway* at Strood, oppoſite to Chatham royal dock-yard. Tide-locks and entrance baſons are to be made at each of the three terminations of this canal; Mr. *Ralph Dodd* was the projector of this canal, on which Mr. *John Rennie* and Mr. *Ralph Walker* have ſince been employed. In December 1801, this canal was completed from Graveſend to Denton. The company were authoriſed to raiſe by the firſt act 60,000l. in 100l. ſhares, and a further ſum by the laſt act, and they are to pay 1s. annually to the city of London as conſervators of the *Thames* river, for the liberty of connecting therewith, and 1s. to the corporation of Rocheſter, as conſervators of the *Medway*, for the ſame privilege.

Thames and Severn Canal. Act 23, 31, and 36 of Geo III.—The general direction of this canal is Eaſt, for 30¼ miles in the counties of Glouceſter and Wilts: it croſſes the Grand Ridge by a tunnel; its objects are a communication between the Severn and Thames rivers, the ſupply of the country through which it paſſes with coals, deals, &c. and the export of farming products. Stroud is the 114th Britiſh town, with a population of 5,422 perſons; Minchinghampton, Cirenceſter, Cricklade, and Lechlade, are alſo conſiderable towns on or near to this canal; which com-

mences in the *Stroudwater* canal at Wallbridge near Stroud, and terminates in the *Thames and Isis* navigation at Lechlade: it has a branch of about 1 mile in length to the town of Cirencester. From the *Stroudwater* canal to Sapperton or Salperton, 7⅞ miles, is a rise of 243 feet by 28 locks; thence, the summit pound continues through the Tunnel, 2⅜ miles, to near Coates, and level; thence, to the *Thames and Isis* navigation, 20⅝ miles, is a fall of 134 feet by 14 locks. The first 4 miles of this canal from Stroud to Brinscomeport Bason, is of the same width and depth as the *Stroudwater* canal, and is navigated by the *Severn* boats; the remainder of the line is 42 feet wide at top, 30 at bottom, and 5 feet deep; at Brinscombe-port, goods going eastward are removed into barges 80 feet long and 12 wide, which carry 70 tons each. The famous tunnel on this canal at Sapperton, is 4300 yards long, the arch being 15 feet wide in the clear, and 250 feet beneath the highest point of the hill, which proved to be hard rock, much of which required blasting, and some of it was so solid as to need no arch of masonry to support it; the other parts are arched above, and have inverted arches in the bottom; the cost of excavating this tunnel, in 1788, amounted to 8 guineas per cubic yard. The summit level of this canal is supplied by a feeder brought through lord Bathurst's gardens. Mr. *Robert Whitworth* and Mr. *Joseph Clowes*, were the engineers. On the 20th of April, 1789, the Sapperton tunnel was finished, and on the 19th of November of the same year, the whole line was completed and opened. We are sorry to have heard it remarked, that this canal has been conducted through porous gravelly soils, when a line for the same, equally convenient, might have made the cutting fall in a clay soil, and that puddling has been in too many instances neglected or has failed, by which the canal is rendered short of water, and the land and mills have been greatly injured: fanciful round buildings like towers have been made in different places on this canal, for the residence of the lock-keepers. This company were authorised to raise 255,000l., the shares being 100l. each; there was a provision that 3 per cent. interest should be paid (out of the principal) to the subscribers on their shares, until the canal was completed and opened; we have heard that the present profits are not much above 1 per cent. No stamps were necessary to the proceedings of this company. The rates of tonnage and the regulations thereof with the *Stroudwater* company, are very long. See *Phillips's* 4to. *History*, pages 222 to 225. Manures for the adjoining lands are to pass toll free: less than 6 tons not to pass the locks without paying for that weight; ½ mile-stones to be erected. In 1799, this company offered bounties for introducing the coals brought by their canal to the western parts of Oxford and Berk shires. The *Gloucester and Berkley* company are to compensate this company, in case the construction or repair of their works interrupts at any time the communication with the *Severn*. In September 1800, it was intended to make from near Inglesham a forked branch passing Faringdon and Highworth, to connect with the *Wilts and Berks* canal in two places.

THANET'S CANAL. Act 13 Geo. III.—The direction of this canal is nearly N.E. for about ½ of a mile in length, in the West Riding of Yorkshire; it is considerably elevated, near to Skipton, which is a considerable town; it commences in the *Leeds and Liverpool* canal, near Skipton, and terminates at Skipton-castle, lime-stone quarries. It was cut at the private expence of the *earl of Thanet*, through whose estate alone it passes, except one close: its object is to convey coals to the lime-kilns, and to export lime as a manure and for building.

THYRN AND BURE NAVIGATION. The general direction of these rivers is about N.W. for nearly 30 miles in the county of Norfolk: they are not greatly elevated above the sea in any part: the objects are the import of coals, deals, &c. and the export of farming products. Yarmouth is the 27th British town, with a population of 14,845 persons; Aylesham is also a considerable town on this navigation, which commences in the *Yare* river Yarmouth, and terminates at the town of Aylesham: it has branches from near Thurne and Horning, through the fens and broads, to Hickling and Dilham, about 8 and 10 miles in length.

TIEV RIVER. This river, (sometimes called the Tivey or Teifi river,) has nearly an east course for about 39 miles, between the counties of Cardigan and Pembroke, and Caermarthen in South Wales: its eastern end is considerably elevated: its objects are the supply of Llanbedr and Cardigan, and the export of agricultural products. Cardigan, Kilgerran, Newcastle-in-Emlyn, and Llanbedr, are considerable town on this river, which commences in the tideway in St. George's channel, and terminates at Llanbedr, or Lampeter.

TONE AND PARRET NAVIGATION. Acts 10 and 11 William III. 6 Anne, and 44 Geo. III.—The general direction of this navigation is nearly south, by a bending course of about 27 miles in the county of Somerset: its southern end is considerably elevated: its objects are the import of coals, and the export of agricultural products; at Borough chapel it is joined by the *Parret* river. Taunton is the 106th British town, with a population of 5,794 persons. Bridgewater is also a considerable town on this navigation, which commences in the tide-way in Brigewater-bay, at Start point, in the Bristol channel, and terminates in the *Grand Western* canal at the town of Taunton. In September 1798, a cast-iron bridge was completed, consisting of one arch of 75 feet span over the *Parret* river at Bridgewater, at the expence of 4000l. (See our article BRIDGE). It was erected in the place of a stone bridge, said to have been built about the year 1300. In 1796, the *Bristol and Taunton* canal was proposed to connect with this navigation at Bridgewater.

Topcliff and Pierse-Bridge. In June 1801, it was proposed to form a canal from the *Swale* river at Topcliff to Piersebridge on the Tees river: the intention of this canal was for supplying the north riding of Yorkshire with Durham coals.

TORRIDGE RIVER. The direction of this river is south for three miles, near to the north-west coast of Devonshire: the tide flows through its whole length: it commences in the *Taw* river near Appledore, and terminates at Biddeford bridge: its object are the supply of Biddeford, a considerable town, with coals, &c. and the export of agricultural products. The spring tides rise 18 feet at Biddeford.

TOVEY RIVER. The direction of this river, (sometimes called the Towey), is north, for about 8½ miles, in Caermarthenshire in South Wales: the tide flows through its whole length: its object is the supply of Caermarthen, which is the 113th British town, with a population of 5,548 persons: it commences in the Bristol channel, at St. Ishmael's, and terminates at Caermarthen bridge. In September 1804, it was intended to apply for an act to improve the port, quays, and dock at Caermarthen.

TRENT RIVER, (*lower part*). Act 34 Geo. III.—The general direction of this navigation is nearly S.S.W. by a bending and crooked course of about 116 miles, skirting Yorkshire for a short distance, and through the counties of Lincoln and Nottingham, and between those of Leicester and Derby: it is not greatly elevated in any part: its navi-

gation is of vaſt importance to the country, owing to the many communications which it forms with other rivers or canals: at Keadby it connects with the *Stainsforth and Keadby* canal; at Stockwith, with the *Idle* river, and near the ſame place with the *Cheſterfield* canal; at Torkſey, with the *Foſs-dyke* canal; at Crankleys, in South-Muſkham, with the *Dean* river; at Trent-bridge, near Holme-pierpoint, with the *Grantham* canal, and the *Nottingham* canal; near Sawley, with the *Loughborough* navigation, or Soar river, and the *Erewaſh* canal. Nottingham is the 17th Britiſh town, with a population of 28,861 perſons; and Newark is the 91ſt, with 6,730 perſons. Burton-upon-Strather, Gainſborough, Newark, Southwell, and Bingham, are alſo conſiderable towns near this navigation; which commences in the *Humber* river at Trent-fall, (at the junction of *Ouſe* river, and *Market-Weighton* canal,) and terminates in the Upper *Trent* river at Sawley-ferry, at the junction of *Derwent* river, and the *Trent and Merſey* canal. It has a ſide-cut of 10 miles in length, made in purſuance of the above act, for avoiding 21 ſhoals, and 2 bridges, which occur in 13 miles of the river between Trent bridge, at the commencement of the *Nottingham* canal, and Sawley ferry, at the commencement of the *Trent and Merſey* canal. This cut (ſometimes called *Trent Canal*), has a riſe of 28 feet, and it croſſes and connects with the *Erewaſh* canal near Sawley; it has alſo a ſhort cut and lock into the *Trent* in Beeſton. The lower part of this river is through fens, and is embanked on both ſides: it is ſubject to very great floods: the tide flows to Gainſborough, ſo that ſmall veſſels can come up to that place; but between this and Wilden-ferry, a great number of ſhallows occur, owing, in a great meaſure, to the too great width of the river: Mr. *John Smeaton*, who examined it in 1761, ſtates, that in ſeveral places in the common ſtate of the river, in dry ſeaſons, there was not above 8 inches depth of water; that at ſuch times, without the aid of fluſhes from King's mills upon this river, and the loweſt mills upon the *Derwent*, navigation was impracticable. The 33 of Geo. III. for *Grantham* canal required the proprietors of this navigation to deepen the bed of their river, ſo that there ſhall always be 30 inches deep of water in the drieſt ſeaſons for boats to paſs between the *Grantham* and the *Nottingham* canals, and by which they may alſo now paſs into the *Trent Canal*, for avoiding the ſhallows above Nottingham. An act was paſſed a few years ago for building a new bridge over this river at Gainſborough. In 1801 a new ſtone bridge was intended at Gunthorpe-ford. In the year 1789 and 1790, ſeveral acres of land were gained from the wide muddy banks of this river, ſimply by ſtaking down rows of furzen faggots thereon, to check the current, and encourage the abundant depoſit which this river makes, wherever its waters become ſtationary; (ſee *Agricultural Magazine*, vol. vii. p. 98.) a circumſtance which proves of immenſe advantage in many inſtances, by the warping of land near this river in floody times, to improve it. The flood which happened in the beginning of 1800, forced a new and much ſtraighter courſe for this river below Gainſborough, and occaſioned the old crooked channel to be deſerted. For making the new ſide-cut, or Trent canal, this company were authoriſed to raiſe 23,000l. in 50l. ſhares: and they are allowed to collect a variety of tolls on different parts of this cut and the river. See *Phillips*'s 4to. *Hiſtory*, *App.* pages 169 and 170. But theſe were not to take place until 13,000l. had been expended under the above act, which embraces the improvement of the river, ſo that there may be always 30 inches deep of water, the making of horſe towing-paths, purchaſing the Nottingham hauling-machine, or capſtern, &c. The profits of the Trent canal are not to exceed 7 per cent. By the 33 Geo. III. for *Derby* canal, only half the uſual rates are to be charged on goods paſſing only three miles on this river, in their way to or from that canal: and by 33 Geo. III. for *Grantham* canal, this company are to receive 1½d. per ton for lime, and 3d. per ton for all other goods (except road-materials and manures), which croſs this river, when deepened as above, between the *Grantham* and *Nottingham* canals. In 1760, the *Wilden and Kings-Bromley*, and in 1765, the *Ternbridge and Winsford* canals were propoſed to join this river at Wilden-ferry, where the *Trent and Merſey* canal now joins.

Trent River, (*upper part*). Acts 10 and 11 William III.—The general direction of this navigation is nearly W.S.W. by a crooked courſe of about 19 miles, in Derbyſhire and Staffordſhire, and ſkirting Leiceſterſhire: it is not very greatly elevated above the ſea, in any part: its objects are the carriage of coals, and the export of ſalt, gypſum, earthen-ware, ale, and agricultural products: it connects at Swarkſtone with the *Derby* canal, and has the *Trent and Merſey* canal running the whole length almoſt by its ſide, and communicating with it at its two extremities. Burton-upon-Trent is the only conſiderable town on this navigation; which commences in the lower *Trent* navigation at Wilden Ferry (at the commencement of the *Derwent* river and *Trent and Merſey* canal,) and terminates near Burton, at a branch from the *Trent and Merſey* canal. The *earl of Uxbridge* is the ſole proprietor of this navigation, and all other perſons are reſtricted from erecting or uſing wharfs or warehouſes on its banks without his ſpecial conſent. The earl or his leſſees are entitled to 3d. per ton, on goods navigated on any part of this navigation; which was ſaid, in 1765, to be unimproved, except by the erection of locks at two different mill-weirs; and, more than 20 ſhallows then exiſted, over which boats could not paſs in dry ſeaſons, without fluſhes of water: ſtrange ſtories were at that time related of the conduct of theſe leſſees, and inſinuations were made, that a barge loaded with ſtones was ſunk by deſign in Kings-mill lock, and which lay there almoſt 9 years, and obliged all goods to be unloaded into freſh boats at that place! happily the rivalry of the canal by its ſide, renders ſuch an occurence hereafter unlikely ever to happen. The bridge over this river at Burton-upon-Trent is ſaid to be the longeſt in England, being 1545 feet long, with 34 arches. It may be proper here to remark, that Mr. *Smeaton*, in 1768, recommended the making of a long bridge or water-road adjoining the lower part of this river, between Muſkham and Newark, that ſhould have 300 yards long of clear water-way through its 72 arches! In 1793, the *Bredon* rail-way was propoſed to join this navigation at Weſton Cliff; in 1796, the *Commercial* canal, and in 1797, an extenſion of the *Aſhby-de-la-Zouch* canal was propoſed to connect herewith at Burton.

Trent and Mersey Canal. Acts 6, 10, 15, 16, 23, 25, *two of* 37, and 42 Geo. III.—This canal (ſometimes called the *Grand Trunk*, or the Staffordſhire canal,) has its general direction about E.S.E. by a very bending courſe of 93 miles in the counties of Cheſter, Stafford, and Derby: it croſſes the grand-ridge by a tunnel: its objects are the export of coals, ſalt, pottery-wares, lime, gypſum, Swithland-ſlates, agricultural products, &c. and forming parts of the grand inland communications between Liverpool and Mancheſter, with Hull, Briſtol, and London; at Quiton's-wood in Stoke, it connects with the *Newcaſtle-under-line* canal: at Great Haywood with the *Stafford and Worceſter* canal; at Fradley Heath with the detached part of *Coventry* canal; and at Swarkſtone it croſſes and connects with the *Derby* canal. Although none of the towns on this long canal appear to have ſo many as 5000 inhabitants, yet

Northwich, Middlewich, Sandbach, Newcastle-under-line, Stone, Stafford, Rudgley, Litchfield, and Burton-upon-Trent, on or near to the same, are considerable places. The commencement of this canal is in *Bridgewater*'s canal at Preston-brook, and its termination in the *Trent* lower navigation, at Wilden-ferry near Shardlow, the point of junction of the *Trent* canal, or side-cut, the upper *Trent* navigation, and the *Derwent* river: from Etruria, a principal branch (sometimes called the *Caldon Canal*,) proceeds by Froghall to Uttoxeter, by a very bending course of about 28 miles in length; from this, at Froghall in Kingsley, there is a rail-way branch of $3\frac{1}{4}$ miles to Caldon-low lime works, also from Stanley Moss in Endon there is a canal branch of about $3\frac{1}{2}$ miles to the town of Leek, and from Shelton, a short cut to Cobridge: from Stoke-upon-Trent there is a rail-way branch to Lane-end; and from Etruria another to Handley-green; from Longport to Dale-hall there is a canal-branch, and the same is continued forwards by a rail-way to the potteries at Burslem; there is a cut 1 mile in length to the *Trent* river near Burton. Near Lane-delph, and in Harecastle there are short cuts or tunnels, extending to the pits or seams of coals. From *Bridgewater*'s canal to Middlewich, 18 miles, is a level; thence to near Talk, 11 miles, is a rise of 326 feet by 35 locks; thence along the summit-pound, and through Harecastle tunnel to the Caldon branch at Etruria, 6 miles, is level; thence to the *Stafford and Worcester* canal at Great Haywood, 17 miles, is a fall of about 150 feet and 19 locks; thence to the *Coventry* canal at Fradley Heath, 13 miles, is about 32 feet, and 4 locks; thence to Horninglow wharf, 12 miles, is about 86 feet fall, and 11 locks; thence to the *Derby* canal at Swarktone, 10 miles, is about 16 feet fall, and 2 locks, and thence to the *Trent* river at Wilden-ferry, 6 miles, is a fall of about 32 feet, and 4 locks. From the summit level of the line at Etruria to near Bagnal on the Caldon branch, $5\frac{3}{4}$ miles, is a rise of 75 feet, by 7 locks; thence to Stanley-Moss, 1 mile, is level; thence to Froghall, $9\frac{3}{4}$ miles, is a fall of 61 feet, by 9 locks. From Preston-brook to Middlewich, at the western end, and from Wilden-Ferry to Horninglow near Burton, at the eastern end, the width of the canal at top is 31 feet, at bottom 18, and it is $5\frac{1}{2}$ feet deep; the locks here are 14 feet wide, adapted to river barges of 40 tons burthen; the middle part of the canal, and its branches, are 29 feet broad at top, 16 feet at bottom, and it is $4\frac{1}{2}$ feet deep, the locks being only 7 feet wide; the boats are 80 feet long, 6 feet wide, and carry 18 to 20 tons of lading. There are 16 public wharfs on this canal with warehouses, cranes, weighing-engines, and other necessary conveniences at each. Over this canal there are 258 road and foot bridges, and under it 3 large aqueducts, and 124 lesser ones and culverts. Through Harecastle Hill is a tunnel of 2888 yards in length, and upwards of 70 yards below the hill; this tunnel intersects, and has cross branches to, several veins of coals in the hill, and is also famous for being the first public canal-tunnel constructed in England; the driving of this tunnel, in 1776, cost about 70s. 8d. per yard run: the height of the arch is 12 feet, and its width 9 feet withinside. At Preston-on the-hill near Bridgewater's canal is another tunnel of 1241 yards in length; at Barton in Great Budworth is another, 572 yards long; at Saltersford, or Salters-field, in the same parish, is another of 350 yards long, and there is a fifth tunnel at Armitage, or Hermitage, of 130 yards in length; the heights of these last tunnels are 17½, and their width $13\frac{1}{2}$ feet. At Monks-bridge there is an embankment 13 feet high of $1\frac{1}{4}$ mile in length, and an aqueduct bridge over the Dove river of 23 arches, from 15 to 12 feet wide each. At Alrewas is an aqueduct over the Trent river, with 6 arches of 21 feet span; and near Middlewich is another aqueduct over the Dane, with 3 arches of 20 feet span. In the Rudyerd vale, N.W. of Leek, near the grand-ridge, is a reservoir of 160 acres extent, with an artificial head 30 feet in height; from this a feeder conducts its water to the Leek branch, and thence into the summit pounds of the Caldon branch, and of the main line: there are four smaller reservoirs near the summit, which measure together 60 acres; all waters within 5 miles of the line are allowed for the use of this canal. The rail-way branch to Mr. *Gilbert*'s Caldon lime-works, made about the year 1777 or 1778, was composed of cast-iron bars pinned down upon rails of wood fixed across wooden sleepers, as we have before described; it appears to have been set out, before the true principles of this excellent mode of conveyance were so well understood as at present, being very crooked and with frequent variations in the angle of its ascent; in the last of the above acts, there is a provision made for varying the line of, and improving this rail-way. It is said to have cost, at first, about 1760l. per mile; in 1794, one horse, we are told, for 9 months in the year, made in each week three journeys on four of the days, and two journeys on the other two days, hauling 3 tons 6 cwt. of limestone down each journey, from the quarries at Caldon to Froghall wharf; for forwarding this stone to the canal at Etruria, the company found boats, the bargeman found his own horse and boy, towing lines, &c. and delivered the stone at 9d. per ton, the distance being about $16\frac{1}{2}$ miles. Mr. *James Brindley*, Mr. *John Smeaton*, and Mr. *Hugh Henshall* were the engineers employed or consulted on the works of this canal, which were begun in July 1766; in April, 1773, the line eastward of Harecastle tunnel was completed, and in May, 1777, the whole line was completed and opened: the Leek branch, the extension of the Caldon branch to Uttoxeter, and the Cobridge branch have been undertaken since the year 1797; the Lane-end, Handley-green, and Burslem branches were projected in 1802. The first act above included 6 miles of the west end of *Bridgewater*'s canal, but with a power to assign or make over the same to the duke of Bridgewater, which was accordingly done; the 6th act above assigned 11 miles of the *Coventry* line, between Fradley-heath and Fazeley, to this company, who completed the same, and then sold it in equal moieties to the *Coventry* and the *Birmingham and Fazeley* companies, as before mentioned. This company have been authorised at different times to raise 334,250l. the amount of their shares was 200l. each, until 42 Geo. III., when a division of them was made into 100l. shares. The rates of tonnage are $1\frac{1}{2}$d. per ton per mile, with reasonable wharfage after 24 hours, on all kinds of goods; but paving and road-materials (lime-stones excepted,) and manures pass toll-free on the pounds and through the locks, when water runs waste over their paddle-weirs. The act 33 Geo. III. for *Derby* Canal, granted some rates to this company on goods crossing this canal or passing out of it into the *Trent* by the *Derby* canal; see *Phillips*'s 4to. *History, Appendix*, p. 58 and 59. In the years 1760 and 1765, the *Wilden and Kings-Bromley*, and the *Tern-bridge and Windsford* canals were proposed through parts of the tract now occupied by this canal: in 1793, the *Sandbach* canal was proposed to join near that place, and the *Bredon rail-way* was intended to be connected herewith near Weston-cliff: in 1796, the *Commercial* canal was proposed, to cross this canal at Horninglow near Burton, and again near Burslem; in 1797, an extension of the *Ashby-de-la-Zouch* canal, to join this at Horninglow was proposed; the design of the two last proposals was, an extension of the wide canals for 40 ton boats, and with the same view a plan was, in 1797, mentioned of

widening this canal and its locks, bridges, &c. fo that wide boats might pafs between Fradley-Heath, and the eaft-end of Harecaftle tunnel.

TWEED RIVER. This river feems to be navigable but about 1 mile from the fea to Berwick bridge, between Berwick liberty and a detached part of Durham county. Berwick is the 82d Britifh town with a population of 7,187 perfons; it has a great trade in falmon, which are caught in great quantities in this river, and 40,000 kits of it have been pickled and fent off from this town in one year; 75 to 80 veffels are employed in fifhery, and the trade of this place connected therewith. At Berwick there is a ftone bridge 947 feet long, with 15 arches over this river. At Kelfo feveral miles higher up on this river, a ftone bridge was, in 1798, wafhed away, and a caft-iron bridge was propofed to be erected in its ftead.

TYNE RIVER. Acts 9 and 10 Henry V., 6 and 7 William III., and 41 Geo. III.—The general direction of this river is nearly W.S.W. by a crooked courfe of about 14 miles between Durham and Northumberland; the tide flows through its whole length; its great object is the export of coals. Newcaftle-upon-Tyne is the 10th Britifh town with a population of 36,963 perfons, South Shields is the 65th with 8,108 perfons, and North Shields the 80th with 7,280 perfons; Gatefhead is alfo a confiderable town near this river, which commences in the North Sea at Tynemouth, and terminates at Blaydon in Winlaton. A very peculiar kind of veffels, as before mentioned, is in ufe upon this river for carrying coals from the waggon-roads, or railways, and ftaiths to the fhips; thefe are called keels, and are limited (by 11 and 15 Geo. III.) to $25\frac{1}{2}$ tons of lading, or 8 Newcaftle chaldrons of coals. From an humane fet of Gentlemen refident upon, and concerned in the trade of this river, originated the idea, and they offered a public reward for the *life-boat*, which Mr. *Greathead* brought to perfection, and firft tried at the mouth of this river on the 30th of January 1790. (See the article LIFE-BOAT). The coals from the numerous coal-mines near this river were formerly delivered to the colliers or coal-fhips lying below Newcaftle bridge by means of the keels, but of late years feveral mines have been opened on both fides of the river, and the railways therefrom are conducted to ftaiths or fpouts on the quays, by which means the coals are fhot at once into the holds of the fhips. Wooden rail-ways were, fince about the year 1680, in ufe between the mines and this river, fome of them of confiderable length, thofe to Tanfield-Moor are 10 miles long. In April, 1798, an inclined-plane of 864 yards in length, was opened from Benwell, or Bywell collieries, as before mentioned: in October 1803, a rail-way from Mr. *Temple*'s Jarrow mine (128 fathoms deep) was opened to the river. No lefs than 35 forts of coals, or rather the produce of as many pits, are ufually fhipped from this river for London, amounting to 700,000 chaldrons annually: fee *Edington's Effay*, &c. p. 31. On fome of thefe mines, immenfely large fteam-engines are employed; in 1763, a new engine was erected at Walker colliery, with a cylinder 74 inches diameter and $10\frac{1}{2}$ feet long, which weighed $6\frac{1}{2}$ tons, and was calculated to lift 307cwt. of water by each ftroke of its pump. There is an ancient ftone bridge of 9 arches over this river, which was greatly damaged by a flood in 1771; in the year 1801, it was fuggefted to remove as many of its piers as would form a 144 feet opening near the fouth bank, and to conftruct an iron arch over the fame, high enough for the keels to pafs without lowering their mafts. The confervators of this river, in purfuance of the laft of the above acts, have deepened and improved the fame and its quays; in 1801, a new dry, or graving-dock, was opened at South Shields, capable of receiving fhips at neap tides; in 1802, an act paffed for building a new light-houfe at Tynemouth with reverberating lamps, inftead of a coal fire blown by bellows, before ufed. In the year 1798, it was propofed to make a tunnel or road-arch under the *Tyne* river from North to South Shields for the paffage of carriages and paffengers, and the expence thereof was eftimated at 6,993l. In 1795, the *Newcaftle and Carlifle* canal was propofed to join this river near Newcaftle; in 1796, the *Newcaftle and Haydon bridge*, and in or before 1801, the *Newcaftle and Maryport* were alfo propofed. In 1797, and again in 1802, the *Durham and Chefter-le-Street* canal was propofed to join this river near Gatefhead; and in 1803, the *Tyne and Beamifh* canal was propofed through part of nearly the fame tract.

Tyne and Beamifh Canal. In 1803, it was propofed to make a canal from the *Tyne* river, near Gatefhead, through Gatefhead, Wickham, Lamefley, and Birtly townfhips, to Beamifh iron works and coal-mines.

ULVERSTONE CANAL. Act 33 Geo. III.—The direction of this fhort, but large canal, is nearly N.W. for $1\frac{1}{4}$ mile in Lancafhire; it is level with high-water at ordinary tides, with a fea-lock at its entrance; its object is to admit fhips to Ulverftone town. This canal commences at Hammerfide hill in Morecambe bay in the Irifh Sea, and terminates at the new bafon and wharfs at Ulverftone; the canal is 65 feet wide at top, 30 feet at bottom, and 15 feet deep; the lock is 112 feet long; at the loweft neap tides there is a depth of 9 feet water at the gates, and at fpring tides of 20 feet; a public fwing-bridge is built at Hammerfide. That able engineer, Mr. *John Rennie*, was employed on this canal, and completed it about July 1797. This company was authorifed to raife 7,000l , the amount of their fhares being 50l. each. Coals may be brought to this canal from the *Lancafter* canal, without paying the fea duty; fome iron works have been eftablifhed near Ulverftone fince the opening of this canal.

Uppingham Canal. In 1793, it was propofed to make a canal from the town of Uppingham in Rutlandfhire, to connect with the *Leicefterfhire and Northamptonfhire Union* canal, and provifion is made in its act (33 Geo. III.) for fuch junctions.

USKE RIVER. The direction of this river is nearly N. for about 4 miles in the county of Monmouth; the tide flows through its whole length; its objects are the export of coals, iron, &c. and the trade of Newport; at Pill-Gwnelly it connects with the *Monmouthfhire* canal, and with the *Sirhowy* tram road; it commences in the *Severn* river at Nafh, and terminates at Newport bridge.

Wakefield and Hullet. In September laft (1805) notices were given for a rail way from the *Calder and Hebble* navigation at Bottom boat in Wakefield, to Hullet-hall collieries, with branches to Birftal and Smithic bridge in the weft riding of Yorkfhire.

WARWICK AND BIRMINGHAM CANAL. Acts 33 and 36 of Geo. III.—The general direction of this canal is nearly N.W. for 25 miles in the counties of Warwick and Worcefter; it croffes the grand-ridge without a tunnel; its objects are the fupply of Warwick with coals, &c. and forming part of the moft direct water communication between Birmingham and London; at Kingfwood in Rowington, this canal is joined by a branch from the *Stratford* canal. Birmingham is the 6th Britifh town with 73,670 perfons, and Warwick is the 107th with 5,775 perfons, on the line of this canal; which commences in the *Warwick and Napton* canal in Budbrook parifh near Warwick, and terminates in the Digbeth cut of the *Birmingham and Fazeley* canal at Digbeth near Birmingham; it has a cut of $\frac{1}{4}$ of a mile to

the bason at Saltesford in Warwick. From the *Warwick and Napton* canal, about ¼ a mile, to near Budbrook town, is level; thence 2½ miles to Hatton, is a rise of about 20 locks; thence to the Stratford branch, about 5 miles, is level; thence to Knowle common, about 4½ miles, is level; thence to Knowle-wharf, 1 mile, is a fall of about 7 locks; thence to near Deritend, about 10 miles, is level; thence to the Digbeth branch of *Birmingham and Fazeley*, 1½ mile, is a rise of about 5 locks. At the termination at Digbeth a stop-lock is erected, which the *Birmingham and Fazeley* company may fasten up, whenever the water in this canal is of less depth than 4 feet at such lock. At Hatsley there is a tunnel of 300 yards in length; at Henwood wharf there is an aqueduct over the Blythe river; near Flint Green another over the Cole river; and near its termination at Digbeth another over the Rea river. In May 1796, the northern end of the canal for near 9 miles to Henwood aqueduct was completed and opened; and, on the 19th of December 1799, the whole line was completed and opened. On the 30th of April 1799, a bank of this canal broke, it was said, and the flow of the waters did some damage. This company was authorised to raise 180,000l., the amount of their shares is 100l. each. The rates of tonnage will be found in Mr. *John Cary's Inland Navigation*, pages 56 and 57; paving-stones, road-materials, and manures for adjoining lands (except lime), are to pass free on the pounds, or through the locks when the water runs waste. Husbandry boats, not exceeding 5 feet wide, may be used by occupiers of lands; boats less than 70 feet long, or with less than 20 tons of lading, are not to pass the locks without leave. The *Birmingham and Fazeley* company are allowed to take 6d. per ton on all goods which pass from that canal to this, until they have paid off 3,600l. of their debt, after which they are to take only 5d.; they are also allowed 3d. per ton on all goods passing from this canal to that.

Warwick and Napton. Act 34 and 36 Geo. III.—The general direction of this canal, (at first called the Warwick and Braunston,) is nearly East, for about 15 miles, in the county of Warwick: it is considerably elevated, and terminates near to the grand-ridge, on its West side: its main object is, the opening of the most direct line between Birmingham and London. Warwick is the 107th British town, with 5,775 persons; Southam is also a considerable town near to this canal; which commences in the *Warwick and Birmingham* canal, in Budbrook parish near to Warwick, and terminates in the *Oxford* canal at Napton on-the-hill; near Warwick it crosses the Avon river, on an aqueduct bridge; near Radford and Long-Itchington there are smaller aqueducts. This canal is level with the *Warwick and Birmingham* canal at their junction, and is entitled to the waste water from that canal. This canal was completed on the 19th of December 1799. The company were authorised to raise 130,000l.; the amount of each share being 100l., but by the last act above, the holders of the original 1000 shares, were authorised to contribute any further sums, and to be entitled to a proportionate dividend, with original shares, on such addition. The tonnage rates are adapted to the principle, of making goods pay a higher rate for short distances; see *John Cary's* Inland Navigation, pages 59 and 60: paving-stones, road-materials, and manures for the adjoining lands, (except lime,) are to pass free on the pounds and through the locks when the water runs waste thereat. Boats less than 70 feet long, or with less than 20 tons of lading, are not to pass the locks without leave. The *Oxford* canal company are entitled to a variety of rates on goods passing out of this canal into that, which see in *Cary* as above.

Waveney River. The general direction of this river is nearly S.W. by a bending course of about 23 miles, between the counties of Suffolk and Norfolk: it is not greatly elevated in any part; its objects are the import of coals, deals, &c. and export of agricultural products: Yarmouth is the 28th British town, with a population of 14,845 persons; Beccles and Bungay are also considerable towns, on or near this river; which commences in the *Yare* river at Burgh, and terminates at the town of Bungay.

Wear River. Act 34 Geo. II.—The general direction of this river is nearly S.W. for about 10 miles in the county of Durham; it is not greatly elevated in any part; its principal object is the export of coals. Sunderland is the 34th British town, with 12,412 inhabitants; Durham is the 74th, with 7,530 persons; and Bishops-Wearmouth is the 97th, with 6,126; Monks Wearmouth and Chester-le-street are also considerable towns, on or near this river; which commences in the German ocean at Wearmouth near Sunderland, and terminates at Lumley castle. There is a rail way of 7 miles in length from this river to Eaton-Main colliery, and a great number of others of considerable lengths, for conveying coals to the staiths and spouts where barges and ships are loaded with them. Eighteen different sorts of coals, or rather the produce of so many different pits, are usually shipped from this river for the London market, amounting in the whole to 195,000 chaldrons annually; see *Edington's Essay on the Coal trade*, page 31. In 1761, Mr. *John Smeaton* was consulted, about the building of the first lock on this river near Harraton; the sinking of its foundations being thought to endanger the coal-mines which were working *under* the river at that place, the river was then to be deepened and made navigable, from Briddick-ford to the new bridge, the estimate being 3700l. In the year 1802, a new dry or graving-dock was hewn out of the rock on the North side of the river in Monk-Wearmouth. On the 9th of August 1796, a grand iron bridge of one arch, 236 feet span, and 100 feet high above high-water mark, was completed over this river at Wearmouth near Sunderland, as we have already mentioned in this article, and in our article Bridge. The importance of this bridge, besides its advantage in admitting ships further up the river, will appear from the tolls for passing over it, having been let for the current year at 2080l. At the mouth of this river there are two piers for the improvement of Sunderland harbour; in 1802, a new light-house, 70 feet high, was built on the North pier, furnished with reflecting lamps: during tide-time every night, another light is exhibited below the principal one, as a notice to ships of the proper time to enter the harbour. In 1797, and again in 1802, the *Durham and Chester-le-street* canal was proposed to join this river near Chester, and thence extend the navigation to Durham.

Weaver River. Acts 7 Geo. I. and 34 Geo. II.—The general direction of this river is nearly S.E. by a crooked course of 20 miles in Cheshire: it is but little elevated in any part; its objects are the import of coals and Cumberland red iron-ore, and the export of salt and agricultural products: Frodsham, Northwich, and Middlewich, are considerable towns near this river; which commences in the *Mersey and Irwell* navigation, near Weston, and terminates at Winsford bridge: the rise is about 45¾ feet by 10 locks: the boats are from 50 to 100 tons burthen: the trustees for this navigation were authorised to borrow money at 5 per cent. interest, and 1 per cent. for the risk; in 1759, the debt amounted to 20,200l., borrowed at 5 and 4½ per cent.: this debt has long ago been paid off; and, there being no private interest in the concern, to the amount of 3000l. has been paid in some years, to the county treasurer of Cheshire, to be laid out in amending and repairing the public bridges,

and in the repair of high-ways leading to the falt-works, agreeable to the directions of the firft act. The falt-mines at Northwich are 300 feet deep. In 1804, it was in contemplation to make a fide-cut to this river, from near Frodfham, into the *Merfey* at Wefton or Weftern point, for avoiding the bar or fhoal at the mouth of this river.

Welland River. Act 34 Geo. III.—The general direction of this river is nearly S.W. for about 37 miles in the county of Lincoln, and fkirting the county of Northampton; it is not much elevated above the fea in any part; its objects are the import of coals, deals, &c. the export of Ketton free-ftone, Collywefton white flates, agricultural products, &c.; near Crowland it connects with Catwater, a branch of the *Nen* river. Bofton is the 102d Britifh town, with 5,926 inhabitants; Spalding, Crowland, Market-Deeping, and Stamford, are alfo towns of fome note on this river; which anciently was navigable for confiderable veffels, from Foffdike-wafh to Spalding; but owing to the conftant changes, which have been taking place in thefe furprifing fens, and their outfall into the wafh, we learn, that in 1618, there was not 6 inches' depth of water at low tide in the channel, 2 miles below Spalding; fo that when the commiffioners of fewers infpected the fame, their boat was obliged to be carried in a cart upon the fands for 3 or 4 miles below that town. In 1721, Mr. *Nathaniel Kinderly* (fee his Ancient and Prefent State, &c. page 83) recommended the cutting of a new channel, from near the mouth of Glen river to Wyberton near Bofton, by which the outfall of this river would be into the channel of the *Witham* river, inftead of Foffdike wafh. The fubfequent contractions of the *Welland* river, by embankments near its mouth, fomewhat improved the navigation to Spalding, and delayed until the year 1794 the adoption of Mr. Kinderly's propofed cut: in future the commencement of this navigation is to be in the tide-way of the *Witham* river at Wyberton roads, and it terminates at Stamford bridge. The new cut is to commence near the Ship alehoufe in Wyberton, where there is to be a fea-fluice againft the *Witham*, for the river and flood waters, with gates pointing to fea and to landwards; the threfhold of this fluice is to be one foot below low water mark, and it is to be 50 feet wide in the clear; adjoining to the fluice is to be a tide-lock, for the ufe of the navigation, 60 feet long, and 8 feet wide, in the clear. From this fea-fluice, the cut is to be continued weftward, with a regular afcent in its bottom, to 4 feet below the fill of Vernat's fluice, and is to terminate in the old *Welland* river, near Hooton's Gibbet: the width of the bottom of this new cut is to be 50 feet, and the fides are to batter 2 feet for 1 in height; at the diftance of 50 feet from the edge of this cut on the South fide, and 30 on the North fide, banks 11 feet in height are to be made, to retain the floods and prevent their overflowing the adjoining fens, a precaution which has been adopted through the whole courfe of the fens. Meffrs. *John Hudfon, George Maxwell*, and *Edward Hare*, are appointed commiffioners for fetting out, and employing proper perfons to execute the new cut, fluices, locks, &c. and are to cleanfe the channel of the *Welland* for fome diftance above the new cut, and erect a fufficient dam acrofs the river below the entrance of the fame, at Shepherd's hole, to ftop the tide waters and turn the land waters through the new cut; the rates of tonnage for navigating of which, will be found in *Phillips*'s 4to. *Hiftory, App.* page 179. A bridge is to be built over the new cut at Foffdyke Inn: at Crowland, there is a moft ancient and curious bridge on this river, fpringing from three different abutments, and meeting in the middle. See our article Bridge. In 1797, it was ftated that 10,000l. had been fubfcribed for carrying the above new cut and improvements into effect; and we hope that ere long the fame will be completed. Truftees are appointed in the above act, for receiving the tolls and maintaining the works when completed by the commiffioners. The greater part of the courfe of this navigation from Spalding to near Peakirk upwards, and from Market-Deeping to Stamford, is by modern cuts, on the north-weft fide of the old river, for avoiding its imperfect channel.

Welfhpool and Leominfter. About the year 1794, a canal was propofed from the *Montgomery* canal and *Severn* river near Welfhpool, to the *Leominfter* canal at Woferton; paffing Bifhops-Caftle and Ludlow in its courfe.

Wey River. The general direction of this river, is nearly S.S.W. for $20\frac{1}{2}$ miles in the county of Surrey: it is not greatly elevated; its objects are the import of coals, deals, &c. and the export of chalk and agricultural products; at Weftley near Weybridge, it is joined by the *Bafingftoke* canal. Godalmin, Guilford, and Chertfey, are confiderable towns on or near to this navigation; which commences in the *Thames* river at Ham-Haw near Weybridge, and terminates at the town of Godalmin. From the *Thames* to Guilford bridge, $15\frac{1}{4}$ miles, is a rife of $86\frac{1}{2}$ feet; in this part the channel of the river was very early improved by fidecuts, and pound-locks, (faid to be among the firft erected in England, and to have been introduced by Sir *Richard Wefton*); from Guilford bridge to Godalmin, is a canal $5\frac{1}{4}$ miles, with a rife of $32\frac{1}{2}$ feet; which is fupplied by a feeder from the Wey at Godalmin. In 1791, and again in 1803, this navigation was propofed to be joined near Godalmin by a canal from the *Itching* river, (fee *Portfmouth and Croydon*). In 1800, the *Grand Surrey* was propofed to be extended to this river near Weftley; and in 1802, a branch from the *Grand Junction* canal was intended to connect with this river by means of the *Thames* at Ham-Haw.

Wharfe River. The general direction of this river is nearly N.W. for about 9 miles, between Ainfty Liberty and the Weft Riding of Yorkfhire: it is not much elevated above the level of the fea: its objects are the carriage of coals, free-ftone, &c. and the export of agricultural productions. Tadcafter and Cawood are confiderable towns on or near to this river, which commences in the *Oufe* river near Cawood, and terminates at the town of Tadcafter.

Whitehaven Brook. This brook is navigable but a very fhort diftance, in a S.E. direction at its mouth, which is wide, conftituting the harbour of Whitehaven in Cumberland: its chief object is the export of coals, lime, and freeftone. This harbour, fituate on the Irifh fea, has had feveral acts paffed for its improvement, viz. 7 and 10 Anne, 13 Geo. II., 1, 12, 28, 32, and 45 Geo. III. and in September laft (1805) notices were given for a further application to parliament. Whitehaven is the 62d Britifh town with 8,742 inhabitants. Mr. *John Smeaton* was confulted in 1768, on the building of a north pier, and extending the fouthern one within 200 feet of it. In 1796, a violent ftorm happened, which confiderably damaged the quays of this harbour. There are feveral rail-ways from this harbour, to the famous coal-mines in its vicinity. On the 4th of Auguft 1738, the firft rail or waggon-way was opened at this place, leading to Harrithwaite and Woodhoufe collieries. In 1802, the Henfingham lime-works were opened. On the 9th of Auguft, 1803, the rail-way, 700 yards in length, paffing over Branftyarch, or Road-bridge, to Howgil and Whingill coal-mines, were opened: and in the fame year thofe to Brackenthwaite mine were opened. On 23d March laft (1805) the William Pit, at 750 yards diftance from the north wall of the harbour, was opened. Some of the veins of coals in thefe pits are $7\frac{1}{2}$ to 12 feet thick, and from the whole of them 900 tons or upwards of coals are raifed daily: one of thefe

mines extends ¾ of a mile under the sea, at about 600 feet beneath its bottom; inclined planes, 200 fathoms long, being used, for drawing up boxes of coals and others of water, from the extremities of these workings under the Sea, to the bottoms of the shafts; these boxes are drawn up the planes by horse gins; for which purpose, and dragging the coal-waggons to the shafts, 100 horses are constantly employed under ground in these pits. The fire-damp often proves fatal to the men and horses employed in these works. There is a fine white free stone quarry on the west side of the harbour.

Wibsey and Dewsbury. In 1802, a rail-way was proposed from the *Calder and Hebble* navigation at Ravensbridge in Dewsbury, to Low-moor iron-works in Wibsey, about 7 miles in length.

Wilden and King's-Bromley. In 1760, the line for a canal was surveyed by Mr. *James Brindley* and Mr. *John Smeaton*, from the *Trent* river at Wilden-ferry to King's-Bromley near Litchfield, 25 miles, with a rise of 110 feet by 19 locks, with a branch therefrom to Longridge near Burslem, 30¼ miles, with 106¾ feet rise, by 28 locks; from which last a level branch was again proposed of 3½ miles, to Newcastle-under-line: another branch of 2½ miles, to Litchfield mill-pool, 18 feet rise, and 3 locks, and thence ½ a mile farther with 30 feet rise, and 5 locks: another level branch was proposed of 10 miles, to Fazeley near Tamworth, and thence ½ a mile, to the Tame river, 17 feet rise, by 3 locks. This canal was intended to be 24 feet wide, and 2½ deep, with fords instead of bridges: the estimate was 100,200l. Mr. *Smeaton* suggested an extension of this canal, over Harecastle-hill, by deep-cutting, with reservoirs and steam-engines, for supplying the summit. The *Trent and Mersey*, *Newcastle-under-line*, and *Coventry* canals have since accomplished what this scheme had in view.

Wilts and Berks Canal. Acts 35 and 41 Geo. III.—The general direction of this canal is nearly N.E. by a bending course of about 52 miles, in the counties of Wilts and Berks: it crosses the grand ridge at the foot of the chalk-hills without any tunnel: its objects are the import of coals from both its extremities, the export of farming products, &c. Abingdon, Wantage, Swindon, Wotton-Basset, Chippenham, Calne, Melksham, and Trowbridge, are considerable towns on or near to this canal, which commences in the *Kennet and Avon* canal at Semington, and terminates in the *Thames and Isis* navigation at Abingdon. It has a cut of about 1½ mile to Chippenham, one of about 3 miles to Calne, and another of about 1 mile to Wantage: the summit-level extends from near Wotten-Basset, to near the extremity of Wilts. The locks are calculated for long, narrow boats. On the Calne branch there is a short tunnel, under the road at Cuningham park; and a principal aqueduct-bridge over Broadtown brook near Wotton-Basset. The rise of the road over the canal bridges is nowhere to exceed 3 inches in a yard; the springs and streams within 2000 yards may be taken; the use of inclined-planes instead of locks is provided for in the act; but they will not be necessary, the canal being generally cut through clayey soils that have plenty of water: half-mile stones are to be erected on the canal banks. The company have been authorised to raise 311,900l. the amount of shares being 100l. each. The inhabitants of Calne made an offer, in August 1799, we are told, to cut the branch to that town, on being allowed the tolls thereon for so doing. In August 1799, the western end of the line was completed and filled, and on the 1st May 1801, by the completion of the *Kennet and Avon* to Semington, the junction was formed, and 22 miles of the line to the aqueduct near Wotten-Basset, with the Calne and Chippenham branches, have since been used, principally in bringing in Somersetshire coals. In September 1800, two branches of the *Thames and Severn* canal, by Faringdon and Highworth, were proposed, to join this canal at Uffington and Shrivenham. In 1803, the Aylesbury branch of the *Grand Junction* canal was proposed to connect with this canal by means of the *Isis* river at Abingdon.

Winston and Stockton. In 1768, Mr. *James Brindley* and Mr. *Robert Whitworth* surveyed the line for a canal from the *Tees* river at Stockton in *Durham* county; passing Hartburn, Cothams-stob, Moor-house, Oak-tree, Maidendale, Bank-top, Darlington, Cockerton, Lower-Walworth, Legg's cross, Killerby, and Staindrop, to Winston: with a branch 1¾ mile from Lower-Walworth to the Tees at Piersebridge; another from Darlington, 3 miles to Croft-bridge on the Tees; and another from Cothams-stob, 2 miles to the Tees at Yarm. The rise from Stockton to Winston is 328 feet. A feeder was to be taken from the Tees river, 3 miles above Winston. The export of coals, lime, and lead, was the object of this proposed canal.

Wisbeach Canal. Act 34 Geo. III.—The direction of this canal is nearly S.E. for 6 miles, in the counties of Cambridge and Norfolk; it is but very little higher than the sea, being embanked through the level fens: its object is a communication between Wisbeach and Lynn, instead of an old part of the *Nen* river near it, which is almost grown up. Wisbeach is the only considerable town near this canal, which commences in the *Nen* river at the old sluice in Wisbeach, and terminates in the *Nen* river again at Outwell (at the commencement of Well-creek, a branch of that river leading to the great *Ouse* river): it is straight and level, having flood locks at its extremities. This company were authorised to raise 20,000l. the amount of each share being 105l. All goods entering or passing out of this canal are to pay 3d. per ton, except government stores and baggage, road-materials, manures, and materials for the use of the Fen-Corporation: husbandry boats may also be used toll free, but not pass the locks. The commissioners for the *Nen* navigation are to have 100l. out of these tolls, and the remainder, after paying interest on the debt, is to be applied in the repair and improvement of Well-creek.

Witham (*old*) River. Act Geo. II.—The general direction of this river is nearly N.W. for about 41 miles in the county of Lincoln; it is but little elevated above the sea in any part: its objects are the import of coals, deals, &c., the export of farming products, and forming part of the inland communication between Lynn and Hull, Liverpool, Manchester, &c. Near Tattershall it is joined by the *Horncastle* navigation; at Chapel-hill by the *Sleaford* navigation; and at Wyberton roads the new outfall and navigation of the *Welland* river are to join this river. Lincoln is the 76th British town, with a population of 7,398 persons, and Boston is the 102d, with 5,926 persons; Tattershall is also a considerable town near this river; which commences at the Scap or Scalp in the tide-way of Boston deeps in the Wash, and terminates in the *Fossdyke* canal, or new navigation at Brayford Meer. This river below Boston, about 4 miles, was anciently so deep, and was so much frequented by ships, that in the 6th year of king John, when the merchants of London paid only 836l. as a tax on their lands and goods, Boston contributed 780l. A gradual decay and silting up of the channel and harbour took place to such a degree, that when in 1761 Messrs. *John Grundy*, *Langley Edwards*, and *John Smeaton* examined the state of this navigation, and of the drainage of the adjoining fens, through which this river is embanked on both sides through nearly its whole length, owing to the long neglect of the banks, which should have confined the returning tide and the land-waters, so as to scower the channel, they reported that 30

ton barges could then ſcarcely reach Boſton, while the navigation above that town was entirely loſt, and the ancient channel was in ſeveral places entirely grown up and abandoned by the water, in its ordinary ſtate. Mr. *Smeaton* then recommended the erection of a ſea-ſluice upon this river below Boſton, the ſill thereof as low as low-water, with 3 openings, amounting to 50 feet wide; theſe to be furniſhed with doors pointing to ſea-ward, and draw-gates behind them gauged, or having their tops, two feet below the ſurface of the fens, for always retaining a proper quantity of water in the river in dry ſeaſons; alſo a ſea-lock at the ſame place for the navigation, furniſhed with three pair of gates, two of them pointing to the land and one to the ſea: the ſtraightening, enlarging, and deepening of the river above Boſton to 80 feet at top, 50 at bottom, and 10 feet deep, were recommended, and the erection of three pound-locks, furniſhed with flood-gates or opening-weirs adjoining, below Lincoln, and one other ſuch lock above. The eſtimate for ſuch of theſe works as related to draining, was 38,000l., and for the navigation works 7,370l. It was remarked that Lincoln high-bridge had but 15½ feet clear width of water-way, above which a hard gravelly place, probably an ancient ford, called Brayford head, covered frequently with only 3 feet of water, acted as a weir for holding up the waters of Brayford meer and the *Foſſdyke* canal. When Mr. *Smeaton* was afterwards conſulted in the year 1782, he objected to a navigation lock which had been in the interim erected below Lincoln town, and recommended the cutting off the communication between *Foſſdyke* canal and Brayford meer, by a pound-lock with gates pointing to the canal, and to deepen this river through and above Lincoln bridge, and to remove Brayford head, ſo as to lower the water in Brayford Meer: the principal wharfs appear to have been ſince made, and the trade of Lincoln is now carried on upon this meer or water. By the actsof 32 Geo. III. for *Horncaſtle* and *Sleaford* navigation, thoſe companies were required to contribute equally with this company in the expences of deepening and improving this river through Lincoln high-bridge, and thence to the *Foſſdyke* canal, in the next 7 years; in conſequence of which, goods paſſing on this river to or from the *Horncaſtle* or *Sleaford* navigations, are to pay only half the accuſtomed rates on this river. In 1803 it was in contemplation to further improve the navigation of this river below Lincoln. Much has been written on a prohibition ſaid to exiſt againſt the ſhipping of coals from this river, on account of its preventing a rivalry with Newcaſtle and Sunderland coals in the London market, by the produce of the Yorkſhire, Derby, and Nottingham mines being brought by the *Trent*, the *Foſſdyke*, and this navigation, to Boſton deeps; an expectation not much better founded, we fear, than that the opening of the *Stover* canal would have any effect on the London coal-market.

Worcester and Birmingham Canal. Acts 31, 38, and 44 of Geo. III.—The general direction of this canal is nearly N.E. for 29 miles in the counties of Worceſter and Warwick; it croſſes the grand-ridge by a tunnel: its objects are the export of coals, and a more direct communication between Birmingham and the *Severn* river: at Selly Oak it is joined by the *Dudley* canal, and at Kings Norton by the *Stratford* canal. Birmingham is the 6th Britiſh town, with a population of 73,670 perſons; Worceſter is the 40th, with 11,325 perſons; Bromſgrove and Droitwitch are alſo conſiderable towns near this canal; which commences in the *Severn* river at Diglis juſt below Worceſter, and terminates in the old *Birmingham*, and the *Birmingham and Fazeley* canals, at their junction at Farmers bridge at the upper end of the town of Birmingham. From the *Severn* to Tardebig, 15 miles, is a riſe of 428 feet by 71 locks; thence to the *Birmingham* canal, 14 miles, is level. The width of the canal at top is 42 feet, and the depth is 6 feet; the locks are 80 feet long and 15 feet wide; the boats are of 80 tons burthen. At Worceſter there is a very fine baſon for the canal boats. There are 4 or 5 principal, and ſeveral ſmaller culverts: the principal tunnel at Weſt-Heath is 2700 yards long, 18 feet high, and 18½ feet wide within the arch, the depth of water therein is 7½ feet; at Tardebig is another of 500 yards in length; at Shortwood is another of 400 yards in length; at Oddingley one of 120 yards; and, at Edgbaſton another of 110 yards in length: four of theſe tunnels are upon the ſummit-pound. Near Coſton-Hacket there is an immenſe piece of deep cutting; in 1794, Mr. *Carne*'s machine worked by a horſe at length, was uſed for excavating the ſoil, inſtead of wheeling it out in barrows. Where the ſummit-pound of this canal connects with the *Birmingham*, the *Dudley*, and the *Stratford* canals; ſtop-locks are erected, which the ſeveral companies may ſhut and lock up, when the ſupplies of this or the other canals fail, ſo as to endanger the lowering of the ſummit-pound, to obſtruct the navigation. Mr. *John Smeaton* was one of the engineers to this canal, the ſcheme of which was laid, and a bill was brought into parliament in 1790, but the oppoſition of intereſts, and natural difficulties of this vaſt undertaking then proved fatal to it; the great anxiety and fatigue which Mr. *Smeaton* underwent in this arduous undertaking, are thought to have injured his health and to have ſhortened the days of that very able and excellent man. In May 1796, the eaſtern end of this canal, as far as the *Stratford* canal at Kings-Norton, was completed. The arching of the Weſt-heath tunnel was begun on the 28th of July 1794, the whole of it was turned by the 25th of February 1797, (1780 yards of it having been completed in the year 1796) and in March 1797, the navigation was extended through it to Hopwood wharf, and in the following year, the ſame was extended to the weſtern end of the ſummit-pound at Tardebig. The company were authoriſed by their two firſt acts to raiſe 399,929l. 1s. 1½d.: their whole ſhares being made hereby, of the odd value of 138l. 17s. 9d. each: theſe were ſaid to be depreciated in value almoſt to nothing; but in 1802, they had riſen to 40l. each. The laſt act was for raiſing a further ſum of money for completing the very difficult part of the line, and ſupplying lockage-water, by ſteam-engines to pump it up from the *Severn*, by reſervoirs, &c. which yet remains to be accompliſhed. The rates of tonnage owing to the ſeveral junctions with neighbouring canals are very complicated; ſee *Cary's Inland Navigation*, pages 68 to 70. Two-pence per ton is charged on goods entering the Worceſter baſon from the *Severn* river, to be there unloaded. This company guarantees the future profits of the *Droitwich* company to the extent of 5 per cent. annually on each ſhare, and thoſe of the *Stourbridge* company to 9l. per cent. on each ſhare: they are alſo to compenſate the water-bailiff of Worceſter for his dues on coals ſold on the *Severn* at Worceſter; they are alſo to pay to George Perrot eſq. as owner of the Stratford *Avon* navigation, 400l. per annum for loſs of his tolls on the upper part of that river by the making of this and the *Stratford* canal, beſides making up any deficiency there may hereafter be, in his rents of 1227l. for the tolls on the lower part of that river. About the year 1793, a branch was propoſed, it appears, from this canal near Hanbury-Hall to the *Droitwich* canal at that town.

Wye River. The general direction of this rapid and romantic river is nearly N.W. by a very bending and crooked courſe of about 85 miles, in the counties of Monmouth and Hereford, and Brecknock, in South Wales, and ſkirting

the county of Gloucefter: its northern end is confiderably elevated: its objects are the carriage of coals, and the ex port of agricultural products; at Hereford it is approached very near, if not joined, by the *Hereford and Gloucefter* canal. Hereford is the 89th Britifh town, with a population of 6,828 perfons: Chepftow, Colford, Monmouth, Rofs, and Hay are alfo confiderable towns on or near to this river; which commences in the *Severn* river at Beachley, and terminates at the town of Hay. The tide often rifes in the mouth of this river, to the extraordinary height of 40 feet; Chepftow bridge over the fame, is of great height above the water at low tide. In 1802, and again in 1804, it was in contemplation to make a horfe towing-path by the fide of this river, and by deepening the fhallows in feveral places to improve its navigation. In 1802, the *Dean-Foreft* railway was propofed to join this river at Englifh-Bichnor, we believe; in the fame year notices were given, for an intended rail-way from this river at Hereford, to join the fame again oppofite to Lydbrook; and in March laft (1805) another railway was propofed from this river to the *Monmouthfhire* canal.

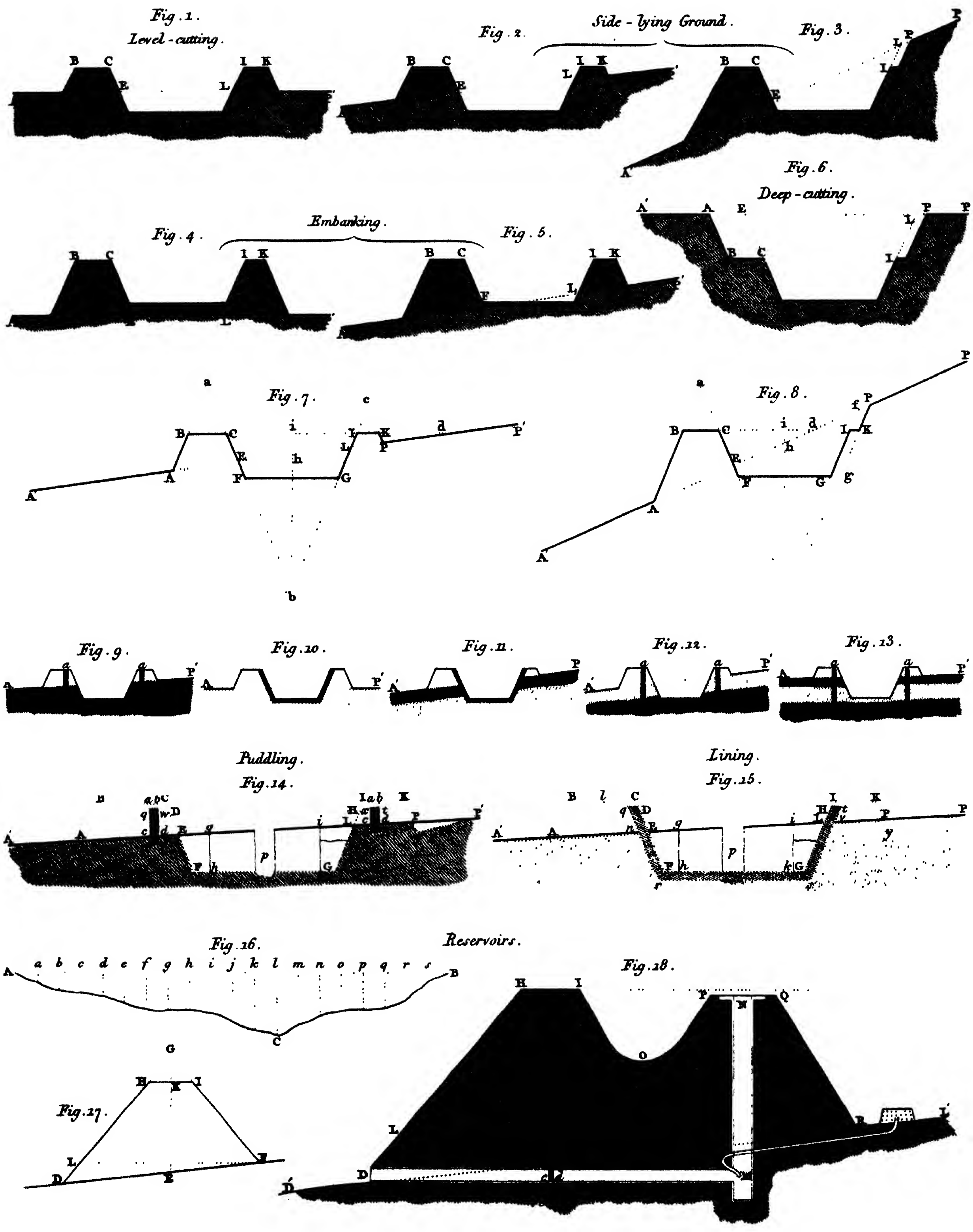
Wyrley and Essington Canal. Acts 32 and 34 Geo. III.—The general direction of this canal is nearly S.W. by a very crooked courfe of 23 miles in the county of Stafford: it is confiderably elevated, and terminates at its weftern end near, or upon the grand-ridge: its object is the export of coals, iron, and lime, which abound in its courfe: Wolverhampton is the 33d Britifh town, with a population of 12,565 perfons; Litchfield and Walfall are alfo confiderable towns on or near to this canal; which commences in the detached part of the *Coventry* canal at Huddlesford (near to Whittington brook, and the commencement of the *Birmingham and Fazeley* canal) and terminates in the old *Birmingham* canal near Wolverhampton: there is a branch of 5¼ miles to Hay-head lime-works; another of 2½ miles to Lord's-Hay coal-pits; another of near 4 miles at Wyrley-bank collieries, with a branch from this laft near 1 mile to Effington new collieries; there is alfo a branch ½ a mile to near Walfall town, which terminates within ½ a mile of the branch of the old *Birmingham* thereto. From the *Coventry* canal to near Cannock-Heath refervoir, 7½ miles, is a rife of about 264 feet, by 30 locks; thence to the old *Birmingham* canal, 15½ miles, is level; the Lords-Hay, Hay-head, and Walfall branches are all level with the long pound: the Wyrley branch rifes about 36 feet, by 6 locks, in the firft ¼ mile, the remainder thereof is level, and therefrom the Effington branch rifes about 24 feet, by 4 locks. This canal is 28 feet wide at top, 16 at bottom, and 4½ feet deep. No water is to be taken from the old *Birmingham* canal, but a lock is erected at the junction, and this canal is to be conftantly kept 6 inches higher than that, or all boats are to be ftopped, by a man ftationed there for that purpofe: the furplus water from this is to be vented into the old *Birmingham* canal. Litchfield water-works pipes were to be carefully guarded in cutting this canal. Branches of 5 miles in length may be made to this canal by the owners of the mines, if they wafte no water. Mr. *William Pitt* was the engineer: and the canal and works were long ago completed. The company were authorifed to raife 160,000l. the firft 35,000l. in 125l. fhares; on the extenfion of the canal in 1794, the company were required to purchafe the fhares of certain difcontented proprietors: the new fhares are 100l. each. The rates of tonnage will be found in Mr. *John Cary's Inland Navigation*, p. 47 and 48. Lefs than 20 tons in a boat is not to pafs the locks without paying for that lading, except empty boats on their return. In 1792, it was propofed to make a branch to Stow-heath, and two others into Afhmore-park.

Yare River. The direction of this river is nearly W. by a bending courfe of about 22 miles, in the county of Norfolk: it is not much elevated in any part; its objects are the import of coals, deals, &c. and the export of agricultural products: at Yarmouth this river is joined by the *Thyrn* river, and at Burgh by *Waveney* river. Norwich is the 11th Britifh town, with a population of 36,854 perfons, and Yarmouth is the 28th, with 14,845 perfons; there are no other confiderable towns near this river; which commences in the German Ocean at Gorlefton-fort, and terminates at the water-works and mill in Norwich: at Yarmouth there is a draw-bridge for admitting mafted veffels above it. The quay of this port is 1⅛ mile in length, and in fome parts 150 yards in breadth: a curious kind of low carriages called Yarmouth-Carts are ufed for conveying the goods from the quay to the warehoufes. In 1804, St. Michael's Coflany bridge over this river in Norwich city was taken down, and a caft-iron bridge erected by Mr. *Froft* in its ftead. In 1785, and again in 1802, the *London Lynn and Norwich*, or North London canal, was propofed to join this river at Norwich.

Yore River. Act 7 Geo. III.—This river, fometimes called the Ure river, has nearly a N.W. direction for about 8½ miles in the Weft, and fkirting the North Riding of Yorkfhire: its objects are the fupply of Borough bridge and Ripon, and the export of agricultural products: at Myton it is joined by the *Swale* river. This navigation commences in the *Oufe* river at Linton, and terminates in the *Ripon* canal at Milby. From the *Oufe* to the *Ripon* canal, is a rife of 11 feet; at Linton river is a lock, and a dam or weir fo made up as to allow about 1 inch per mile in this diftance, for a ftream navigation. Mr. *John Smith* was the engineer, who in 1767 referred to Mr. *John Smeaton* for his opinion on the height of Linton dam, and other matters relating to the works then going on.

For further illuftrating this part of our fubject, we intend to give a map of the Britifh iflands, fufficiently large to diftinguifh all the navigable rivers, canals, rail-ways, harbours, &c.; and having adopted a method, by which the inconveniences of large folding-maps will be avoided, and yet perfect facility be given, of reference from any page of the map to the other, this will probably be the firft of a feries of maps, for defcribing more particularly than has yet been done, feveral ufeful and curious particulars relating to the topography and prefent ftate of our own country.

CANALS.



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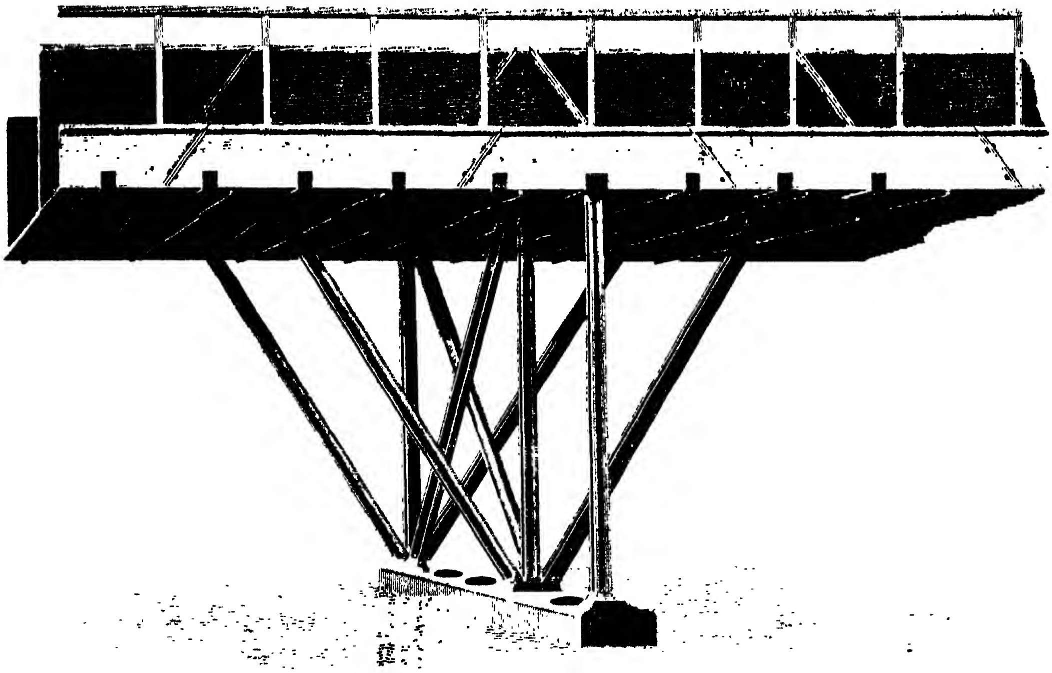
CAST IRON AQUEDUCTS.

Mr. Telford's, on the Shrewsbury Canal at Long.

Fig. 22.



by Mr. Fulton.

Fig. 23.

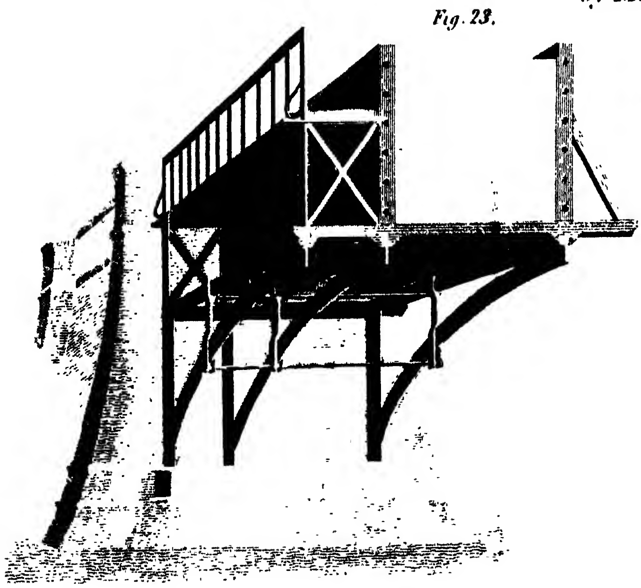
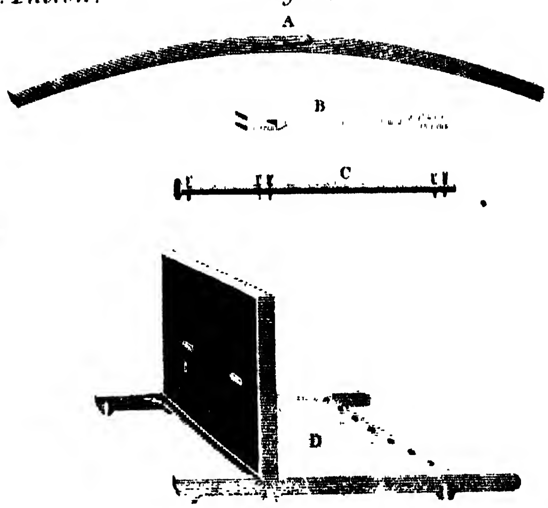


Fig. 24.



J. Farey Junr. delin. Published as the Act directs, 1804, by Longman, Hurst, Rees, Orme & Co. Paternoster Row. Engraved by W. Lowry.

CANALS.

Fig. 25. Embankment

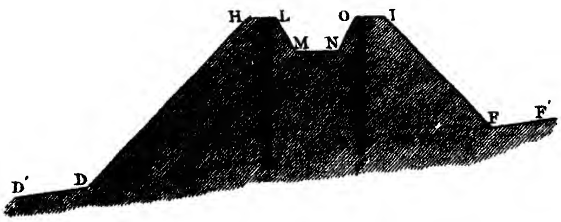


Fig. 26. Safety Gate.

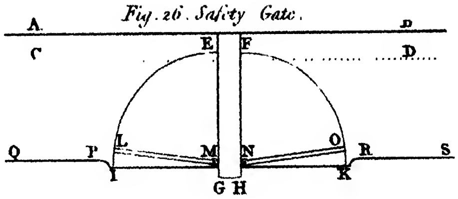


Fig. 27. Weir.

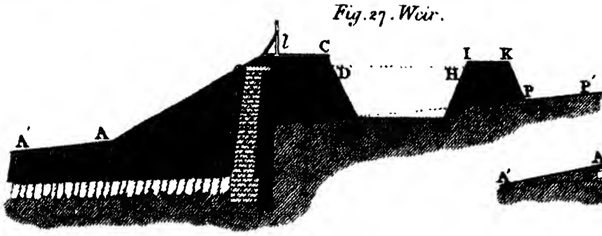


Fig. 28. Circular Weir.

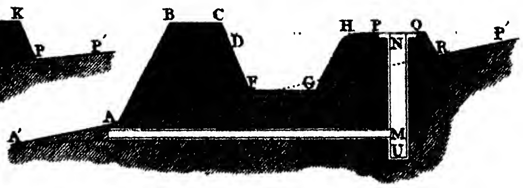


Fig. 29.

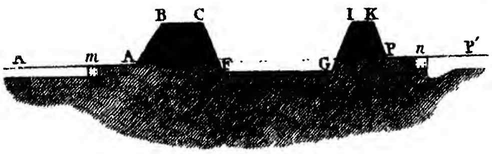
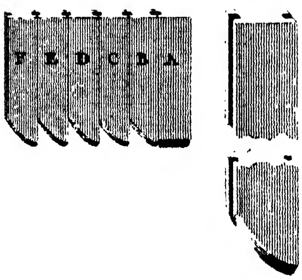


Fig. 30. Pile-planks



Iron Rail-ways.

Fig. 31.

Fig. 34.

Fig. 32.

Fig. 33.

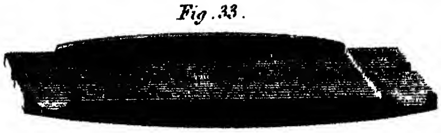
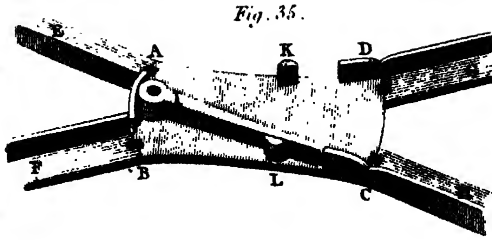


Fig. 35.



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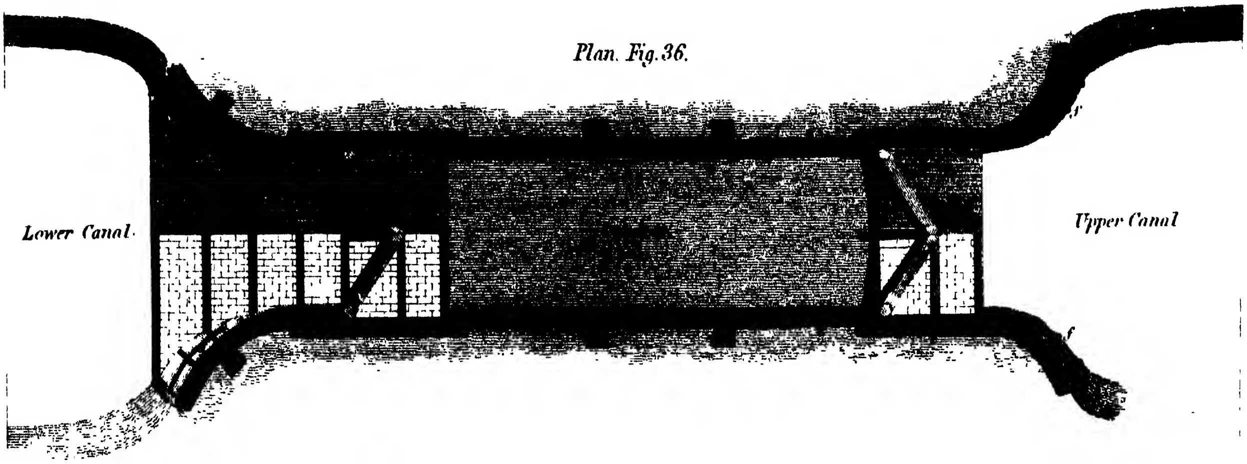
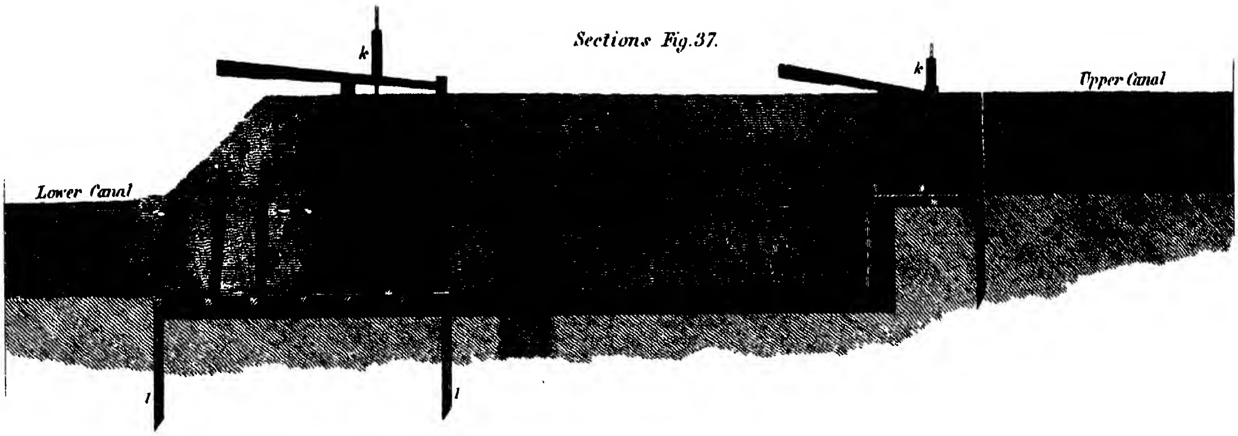
CANALS.

LOCKS.

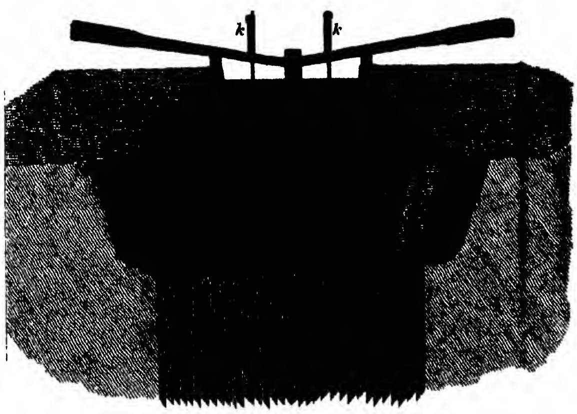
Plan. Fig. 36.



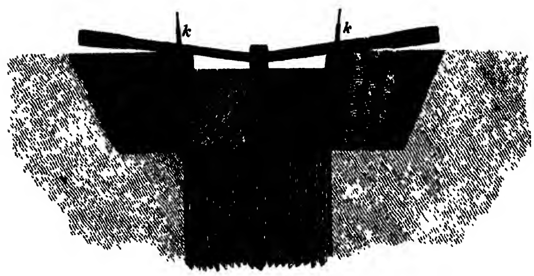
Sections Fig. 37.



Lower Gates Fig. 39.



Upper Gates. Fig. 38.



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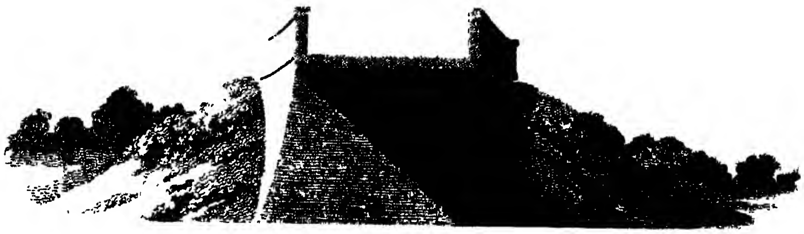
CANALS.

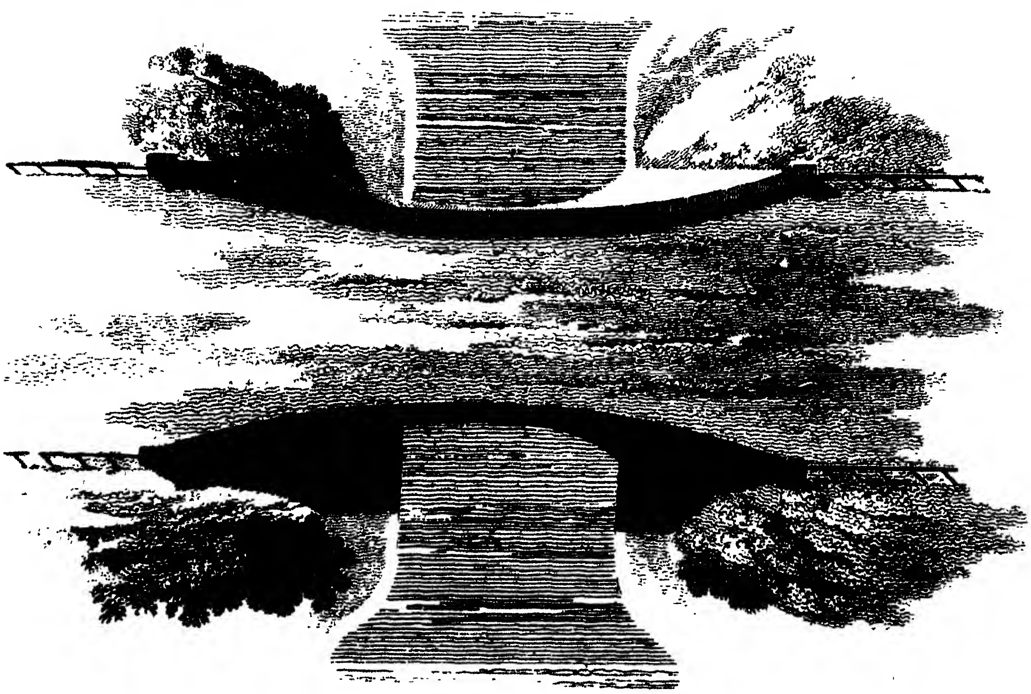
BRIDGES.

View_ Fig. 42.

Section_ Fig. 41.



Plan_ Fig. 40.



CANALS

Swing Bridge

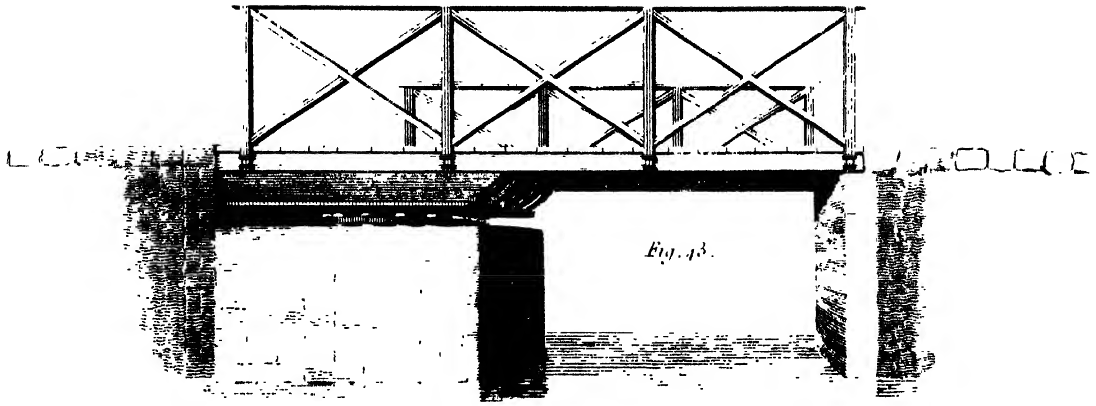


Fig. 43.

Fig. 44.

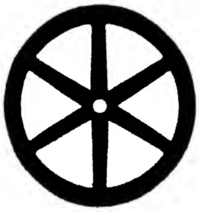


Fig. 45.

Fig. 46.

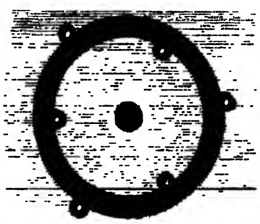
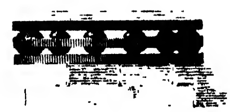


Fig. 47.



NAVIGATOR'S TOOLS &c.

Fig. 48 Barrow.

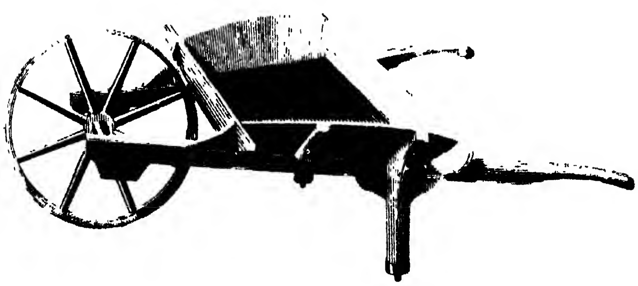


Fig. 49. Horsing-Block.

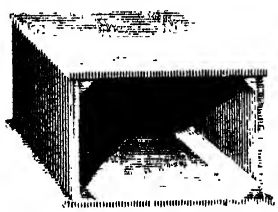


Fig. 50
Grafting Tool.

Fig. 51.
Shovel.

Fig. 52 Scoop

John Farey Jun.r delin.

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Candle

CANDLE, a cotton or linen wick, loosely twisted, and covered with tallow, wax, or spermaceti, in a cylindrical figure; which, being lighted at the end, serves to illuminate a place in the absence of the sun.

The word *candle* comes from *candela*, and that from *candor*, of *candeo, I burn;* whence also the middle age Greek *κανδήλα*.

A tallow candle, to be good, must be half sheep's and half bullock's tallow; the fat of hogs makes them gutter, gives an ill smell, and a thick black smoke.

Tallow candles are of two kinds; the one dipped, the other moulded: the first, which are those in ordinary use, are of an old standing; the latter are said to be the invention of the sieur le Brez, at Paris. The manufacture of the two kinds is very different, excepting in what relates to melting of the tallow, and making the wick, which is the same in both.

Candles, *method of making*. The different kinds of tallow being weighed and mixed in their due proportion, are cut or hacked into pieces, to facilitate their melting, and thrown into a pot or boiler, having a cavity of some depth running round the top, to prevent its boiling over. Being thus perfectly melted and skimmed, a certain quantity of water is thrown in, proportioned to the quantity of tallow; this serves to precipitate the impurities of the tallow, which had escaped the skimmer, to the bottom of the vessel. The tallow, however, intended for the first three dips, must have no water; because, the dry wick imbibing the water readily, makes the candles spit and crackle in the burning. The melted tallow is now emptied through a sieve into a tub, having a tap for letting it out, as occasion requires. The tallow, thus prepared, may be used after having stood three hours; and will continue fit for use twenty-four hours in summer, and fifteen in winter. The wicks are made of spun cotton, which the chandlers buy in skeins; and they wind off three or four together, according to the intended thickness of the wick, into bottoms, or clues, from a certain number of which threads are drawn off, and then cut with an instrument contrived for that purpose, into pieces of the size and length of the candle required. The machine for cutting the cotton consists of a smooth board adapted to rest on the knees; (see *Plate, Candle-Making, fig.* 1.) on the upper surface of which are the blade of a razor, or a knife, A, and a pin or round piece of cane, B, placed at a certain distance from one another, according to the length of the cotton that is wanted: the cotton is then carried round the cane, B, and being brought to the razor, or knife, A, is instantly separated from the several bottoms or balls. The next operation is that of "pulling the cotton," which is that of laying smooth the threads, removing all knots, &c. and thus rendering it fit for use. It is then put on the sticks, or broaches, or else placed in the moulds, as the candles are intended to be either dipped or moulded. The broaches are rods about half an inch in diameter, and somewhat more than three feet long.

Candles, *making of dipped*. The liquid tallow is drawn off from the tub above mentioned, into a vessel called the mould, sink, or abyss, of an angular form, perfectly like a prism, except that it is not equilateral, the side on which it opens being only ten inches high; and the others, which make its depth, fifteen. On the angle, formed by the two great sides, it is supported by two feet, and is placed on a kind of bench, in form of a trough, to catch the droppings, as the candles are taken out at each dip. At a convenient distance from this is seated the workman, who takes three sticks, or broaches at a time, strung with the proper number of wicks, viz. sixteen, if the candles are to be of eight in the pound; twelve, if of six in the pound, &c. and holding them equidistant, by means of the second and third finger of each hand, which he puts between them, he immerges the wicks two or three times for their first lay, and, holding them some time over the opening of the vessel to let them drain, hangs them on a rack, or frame, where they continue to drain and grow hard. When cooled, they are dipped a

second

second time, then a third as before; only for the third lay they are immerged but twice, in all the rest thrice. The operation is repeated more or less times, according to the intended thickness of the candles. With the last dip they neck them; i. e. plunge them below that part of the wick where the other lays ended. Such as we have above described used to be the laborious method of making common candles; till within 15 or 20 years past, when an invention was introduced which served very much to diminish the labour and to facilitate the operation. This method of making dipped candles, as now practised by the manufacturers in London, is as follows: the wicks prepared as above are hung at equal distances upon the broaches; and when five of these are filled, they are put into holes in two pieces of wood, C, D, (*fig.* 2.); thus forming a frame full of wicks. The vessel, A, (*fig.* 1.) is then filled with melted tallow. This vessel is made of lead, and has a hole, B, under it for receiving a chaffing-dish to keep the tallow warm; on each side of the vessel are two leaves, C, D, for catching the droppings of the candles as they are dipped; over the vessel is suspended from the ceiling a framed lever, K, K, with two arched heads, L, L, at each end, in order to give a vertical motion to the scale, I, and frame, EFGH, the two cross pieces, E, F, of which are for the leaves, C, D, of *fig.* 2. to rest upon. The dipper then lays hold of the upper bar at G and H, and gently pushes down the wicks into the melted tallow, and keeps them down till he finds that, by the tallow adhering to them, they are heavier than the weight in the scale I, previously adjusted to the proper weight. The frame of candles is then removed and hung up to cool, which takes some days, according to the state of the weather. When they are quite stiff, they are dipped again with a heavier weight in the scale I, and this operation is continued, till they are of the proper size. The workman, by means of this simple contrivance, has only to guide the broaches and candles, and not to support the weight of them as in the old method.

It must be observed, that during the operation the tallow is stirred from time to time, and the stock supplied with fresh tallow. When the candles are finished, their peaked ends, or bottoms, are taken off; not with any cutting instrument, but by passing them over a kind of flat brazen plate, heated to a proper pitch by fire underneath, which melts down as much as is requisite.

Candles, *method of making mould.* These candles are made in moulds of different materials; that generally used is pewter. Each candle has its mould, consisting of three pieces, the neck, shaft, and foot: the shaft is a hollow pewter cylinder, B, (*fig.* 6.) having the end *a* somewhat smaller than the other, that the candle may slide out easily, of the diameter and length of the candle proposed; at the extremity of this is the neck, A, which is a little metallic cavity, in form of a dome, having a moulding withinside, and pierced in the middle with a hole big enough for the wick to pass through. At the other extremity is the foot, in form of a little tunnel, through which the liquid tallow runs into the mould. The neck is soldered to the shaft, but the foot is moveable, being applied when the wick is to be put in, and taken off again when the candle is cold. A little beneath the place where the foot is applied to the shaft, is a kind of string of metal, which serves to support that part of the mould, and to prevent the shaft from entering too deep in the table to be mentioned hereafter. Lastly, in the hook of the foot, is a leaf of the same metal, soldered within side, which, advancing into the centre, serves to keep up the wick; which is here hooked on, precisely in the middle of the mould: The wick is introduced into the shaft of the mould by a piece of wire, which being thrust through the aperture of the hook, till it come out at the neck, the wick is tied to it; so that in drawing it back, the wick comes along with it, leaving only enough a-top for the neck: the other end is fastened to the hook, which thus keeps it perpendicular, E E (*fig.* 5.) Ten or fifteen of these moulds, in this condition, are fixed in a frame pierced full of holes, the diameter of each being about an inch, by a screw at the top of each mould, which attaches them to the upper board B of the frame. This board has three upright sides and one sloping, which forms a small cistern for the tallow. When every mould in the frame has been provided with a wick, two wires, *c c*, (*fig.* 5.) are passed through the two ends of the cistern at the top of the frame, and the loops of the several wicks. The ends of the wicks which hang out of the mould are pulled tight, their tops are put over the centers of the moulds, and the friction of the mould keeps them in this position. These moulds are filled with tallow out of a cistern, A (*fig.* 4.) the outside of which is wood, and lined with lead; within which is another cistern of lead for containing the melted tallow, prepared as above, with about two inches space between them all round to be filled with hot water for keeping the tallow warm. In the bottom of the vessel are three small shuttles, B, C, D, communicating with the inner vessel, and serving to fill the moulds, E E, before described. After the frame is filled and the tallow has acquired its due consistence, the two wires, *c c*, are withdrawn, and the loose tallow in the cistern at the top of the frame scraped out; they are set out in the open air to cool, and when thoroughly cold, the candles are pulled out of the mould by a bodkin put through the loops of the wicks where the wires, *c c*, passed before.

Those who aim at perfection in their work, bleach or whiten their candles, by fastening them on rods or broaches, and hanging them out to the dew, and earliest rays of the sun, for eight or ten days: care being taken to screen them in the day-time from the too intense heat of the sun, and in the night from rain, by waxed cloths. Tallow-chandlers make other candles, which are intended to burn during the night without the necessity of being snuffed. The wick of these has been usually made of split rushes; but of late, very small cotton wicks have been substituted for the rush; these are much more easily lighted, are less liable to go out, and, on account of the smallness of the cotton wick, they do not require the aid of snuffers. The price of candles used formerly to be regulated by the masters and wardens of the tallow chandlers' company, who were accustomed to meet at their hall every month for the purpose; but now the price of every article belonging to the trade is fixed at the weekly markets.

Candles, *wax*, are made of a cotton or flaxen wick, slightly twisted, and covered with white or yellow wax. Of these there are several kinds; some called tapers, used to illuminate churches, and in processions, funeral ceremonies, &c. and others used on ordinary occasions.

As to the first kind, their figure is conical, still diminishing from the bottom, which has a hole to receive the point in the candlestick, to the top, which ends in a point: the latter kind are cylindrical. The first are either made with a ladle, or with the hand.

Candles, *wax*, *manner of making with the ladle.* The wicks being twisted, and cut off at the proper length, a dozen of them are tied by the neck, at equal distances, round an iron circle, suspended directly over a large bason of copper tinned, and full of melted wax: a large ladle full of this wax is poured gently, by inclination, on the tops of the wicks, one after another; so that running down, the

whole wick is thus covered; the surplus returning into the bason, where it is kept warm by a pan of coals underneath it. They thus continue to pour on the wax, till the candle arrive at its destined size: still observing, that the three first ladles be poured on at the top of the wick, the fourth at the height of $\frac{3}{4}$, the fifth at $\frac{1}{2}$, and the sixth at $\frac{1}{4}$; by which means the candle arrives at its pyramidal form. The candles are then taken down hot, and laid aside of each other, in a feather-bed folded in two, to preserve their warmth, and keep the wax soft: they are then taken and rolled, one by one, on an even table, usually of walnut-tree, with a long square instrument of box, smooth at the bottom. The candle being thus rolled and smoothed, its big end is cut off, and a conical hole is made in it.

Candles, *wax, manner of making by the hand.* The wick being disposed, as in the former, they begin to soften the wax, by working it several times in hot water, contained in a brass caldron, tinned, very narrow and deep. A piece of the wax is then taken out, and disposed, by little and little, around the wick, which is hung on a hook in the wall, by the extremity opposite to the neck; so that they begin with the big end, diminishing still, as they descend towards the neck. In other respects, the method is the same here as in the former case; only that they are not laid in the bed, but are rolled on the table, just as they are formed. It must be observed, however, that in the former case, water is always used to moisten the several instruments, to prevent the wax from sticking; and in the latter, lard, or oil of olives, for the hands, table, &c.

Candles, *wax cylindrical,* are made either with the ladle, or drawn. The first kind are made of several threads of cotton, loosely spun, and twisted together, covered with the ladle, and rolled, as the conical ones, but not pierced.

Candles, *wax, drawn,* are so called, because actually drawn, in the manner of wire, by means of two large rollers, or cylinders of wood, turned by a handle, which turning backwards and forwards several times, pass the wick through melted wax, contained in a brass bason; and at the same time through the holes of an instrument, like that used for drawing wire, fastened at one side of the bason: so that, by little and little, the candle acquires any bulk, at pleasure, according to the different holes of the instrument through which it passes: by this method, may four or five hundred ells at length be drawn, running. The invention of this was brought from Venice by Pierre Blesimare of Paris, about the middle of the 17th century.

The ascent of the tallow up the wick in a burning candle, may be resolved into the same principle of filtration, or attraction, as that of water up a heap of ashes, or even up a capillary tube. The wick of a candle is but slightly twisted, that all its hairs may be easily come at; which being very small, soon take the flame: and the flame by its heat rarefying the air, and dissolving the tallow underneath, makes the globules thereof ascend into the rarefied spaces of the wick, and these, with the air about it, prove food for the flame.

A patent was granted in 1799, to Mr. William Bolts of London, for new modes of improving the form, quality, and use of candles. The most material alteration in Mr. Bolts's invention from the common method of making candles, consists in saving the greater part of the wick by rendering it moveable; and for this purpose it is kept constantly soaking in the tallow as it melts, so that the cotton is consumed very slowly as in lamps fed with oil. The patentee employs two methods for accomplishing this object; one is that of making candles entirely solid, without any wick passing through them; and applying the wick, which is very short, upon the top of the solid candle, where it burns like that of a lamp; the heat which it affords when first lighted being sufficient to furnish the first supply of melted tallow, and to continue it as long as any part of the candle remains unconsumed. In order to keep the wick constantly applied, it is fastened to a small projecting spring, into which it is firmly fixed; and the surface of the candle is always kept in contact with the wick, either by causing the wick stand to pass round the candle like a collar, which moving freely on the candle, will sink in proportion as this is consumed, or by making the wick stand immoveable, and putting a spiral spring at the bottom of the candlestick, which constantly protrudes the candle upwards against the wick in proportion as the tallow is consumed. His second method of constructing the candles is that of forming them in the usual shape, but with a perforation through their whole length; and the wick in this case is a small tuft of cotton, which is put into the opening at the top of the hollow candle, and to its lower part is attached a thread which passes down through the perforation to the bottom of the candle, where it penetrates the candlestick, and is wound round a key or pivot, and by turning this pivot, the wick that is attached to the upper part of the thread will be pulled down in proportion as the candle consumes. This method prevents the guttering of candles, as all the tallow that is melted is readily absorbed by the wick. By a small variation in the form of the candle, it may be made to serve the purpose of an Argand's lamp; for which end it is composed of a hollow cylinder of tallow, including another cylinder also perforated; and the wick, which is of a circular form, is here placed between the inner and outer cylinders. In all these cases, the wick is composed of thread, placed longitudinally, and not twisted, as is the case with the common wicks, which undoubtedly assists the capillary attraction of the melted tallow. These wicks have also the advantage of not requiring to be snuffed, for removing the carbonaceous matter which escapes unconsumed from the tallow. Another advantage attending these detached wicks, is the ease with which their bulk may be proportioned to that of the candle, and to the fusibility of the material of which it is composed. The patentee also proposes another improvement, which is that of subjecting the melted tallow or other material to a considerable pressure, during the act of cooling; which is done by means of a condensing machine, pressing the surface of the liquid substance, and then giving it a greater degree of firmness and solidity when cold. The patentee has likewise described, and illustrated by a drawing, the contrivance which he has adopted for casting the hollow cylindrical candles. For a detail of other circumstances that occur in his patent, we refer to his specification in the Repertory, vol. xii. p. 368.

Candles, *laws relating to.* Every maker of candles for sale, other than wax candles, shall take out an annual licence at 1l. 24 Geo. III. c. 41. 43 Geo. III. c. 69. And every person making wax or spermaceti candles shall take out a licence at 6l., and for dealing in, or selling such candles shall pay 10s. 6d., and renew the same annually, under a penalty of 20l. 24 Geo. III. c. 36. 43 Geo. III. c. 69. But no person who hath paid such licence duty for making, shall be obliged to take out a licence for selling also, during the same year. 24 Geo. III. c. 41. By 24 Geo. III. c. 74., no person, residing within the limits of the head-office, shall be permitted to make candles, unless he occupy a tenement of 10l. a year, assessed in his own name, and for which he pays the parish rates; and elsewhere, unless he be assessed and pay to church and poor. By 43 Geo. III. c. 69., in lieu of any subsisting duties of excise, the following duties are imposed; viz. for every pound avoirdupois of candles, except those of

wax and fpermaceti, made in Great Britain, 1d.; and for every pound of wax or fpermaceti candles fo made, 3½d. All places for making or keeping of candles, and of materials for the fame, and furnaces, moulds, &c. for melting fuch materials, are forbidden to be ufed without notice previoufly given in writing at the next office of excife, under a penalty of 50l., and forfeiture of all candles and materials, furnaces, &c. which have not been entered. 8 Ann. c. 7. And by 11 Geo. c. 30., makers of candles who make ufe of fuch places or utenfils without entry incur a forfeiture of 100l. Officers fhall be permitted, at all times by day, and alfo in the night with a conftable, to enter the houfe, melting-houfe, &c. of a maker of candles, and to take an account of the quantity, when all chefts, &c. fhall be opened; and the penalty of obftructing or molefting fuch officer is 100l.; or if candles, &c. be found in unentered places, the offender fhall be convicted in the penalty of 100l. 11 Geo. c. 30.; fee alfo 24 Geo. III. c. 11. and 27 Geo. III. c 31. Any maker of candles fhall give notice in writing to the proper officer of his intention to begin a courfe of dipping and preparing for the fame, with a declaration of the time when he intends to commence his operation, and a fpecification of the number of fticks, moulds, &c. which he propofes to ufe, under a penalty of 50l. 10 Ann. c. 26. 11 Geo. c. 30. 24 Geo. III. c. 11. Such notice fhall be given, within the limits of the head-office, 6 hours, within any city or market town, 12 hours, and elfewhere 24 hours, before he fhall begin, on pain of forfeiting 50l. 25 Geo. III. c. 74. If he does not begin and proceed at the time mentioned, or within 3 hours next after, fuch notice fhall be void. Having begun, he fhall continue working without interruption, till the whole courfe is finifhed, on pain of forfeiting 50l. 26 Geo. III. c. 77. Every candle maker fhall provide fufficient locks and faftenings to every furnace, copper, mould, &c. to be fecured by the officer, when they are not ufed; and he fhall give notice in writing to the faid officer, 6 hours before the time when he wifhes to ufe them, within the limits of the chief office, 12 hours in any market town, and 24 hours elfewhere; any offence againft the provifions of this act incurs a penalty of 100l. 27 Geo. III. c. 31. The officer fhall charge for materials that are miffing, after he has taken account of the fame; and obftruction incurs a forfeiture of 20l. Candles that are fpoiled in making fhall be defaced by the officer, and he fhall make allowance for the duty. No maker of candles fhall, on pain of 20l., remove candles before they are furveyed; and thofe that have not been furveyed are to be kept feparate from the others, on pain of 5l. 8 Ann. c. 9. On fufpicion, that candles are privately made, or concealed to evade the duty, the ground of which has been ftated on oath before two commiffioners or one juftice refiding near the place, the officer may be empowered by fpecial warrant, granted by fuch juftices or commiffioners, to enter the place fufpected, and to feize as forfeited all candles that are found, and all materials for making them; and the perfon fo offending, or obftructing the officer, fhall forfeit 100l. 5 Geo. III. c. 43. 23 Geo. II. c. 24. If any chandler fhall mingle candles not weighed by the officer with thofe that have been weighed, or remove any before weighing, or conceal any candles or materials, he fhall forfeit 100l. 11 Geo. c. 30. Any perfon who is found affifting in privately making candles fhall forfeit 20l.; and every perfon making candles fhall once in every week enter the fame in writing at the next excife-office, with their weight, number, fize, and quantity; on pain for every neglect of entry to forfeit 20l.; and in one week, after fuch entry, he fhall clear off the duties, on pain of double duty, nor fhall he carry out candles till the duty hath been paid, on pain of double value. 25 Geo. III. c. 74. Perfons buying, receiving, or having in their poffeffion candles, not charged with the duty, fhall forfeit the fame, and treble value. 26 Geo. III c. 77. Nor fhall any perfon expofe to fale any candles, unlefs in his public fhop or warehoufe, public fair or market, on pain of 5l. 8 Ann. c. 9. No candles fhall be imported, otherwife than in fome package containing at leaft 224lb. of neat candles, on pain of being feized and forfeited, and the mafter of the veffel fhall forfeit 50l. 23 Geo. II. c. 21. 42 Geo. III. c. 93. And no candles imported otherwife than according to 23 Geo. II. c. 21., fhall be entered for exportation. 42 Geo. III. c. 93. All wax candles feized on importation or otherwife, and condemned for non-payment of the duties, fhall be rendered unfit for ufe. 24 Geo. III. c. 36. Candles for which the duty hath been paid may be exported, with a draw-back of the duty. 8 Ann. c. 9. 43 Geo. III. c. 69. If any maker of candles fhall obftruct any officer in the execution of the powers given him by any act for fecuring the duties on candles, he fhall for every fuch offence forfeit 100l. 24 Geo. III. c. 11. Every maker fhall keep juft fcales and weights, and permit and affift the officer in the ufe of them, on pain of 10l. 8 Ann. c. 9.; and if he ufe fcales and weights that are infufficient, he fhall forfeit 100l. 10 Geo. III. c. 44.; and by 28 Geo. III. c. 37, the fame fhall be forfeited, and may be feized by any officer of excife. Obftruction of the officer in weighing or the hindrance of his taking a juft account of ftock, fubjects to a forfeiture of 100l. 26 Geo. III. c. 77.

Candles, *Obfervations on the manufacture, comparative value, and ufe of different.* The Roman candles were at firft little ftrings dipped in pitch, or furrounded with wax; though afterwards they made them of the papyrus, covered likewife with wax; and fometimes alfo of rufhes, by ftripping off the outer rind, and only retaining the pith. For religious offices, wax candles were ufed; for vulgar ufes, thofe of tallow. Serv. ad. Æn. l. i. v. 731. Plin. Nat. Hift. l. xvii. c. 37. Lord Bacon propofes candles of divers compofitions and ingredients, and alfo of different forts of wicks; with experiments on the degrees of duration, and light of each. Good houfewives are faid to bury their candles in flour, or bran, which, it is faid, increafes their durability, almoft one half. Some fpeak of perpetual candles made of Salamander wood. Bac. Nat. Hift. Cent. 4. c. 369. and Cent. 8. c. 744.

The two fubftances moft commonly ufed in the manufacture of candles are wax and tallow. Wax owes its whitenefs, and the greater confiftency it acquires, to an abforption of the vital part of the atmofphere; and in this circumftance it feems principally to differ from tallow, or concrete oil. But as wax is already combined with a portion of vital air or oxygene, it does not burn with fo luminous a flame as tallow or oil. But it poffeffes a very great advantage in the fabrication of candles, arifing from its freezing point being placed at a confiderably higher temperature than that of the other fubftance. Tallow melts at the 92d. degree of Fahrenheit's thermometer; fpermaceti at the 133d. degree; and bleached wax at 155°. Hence it will not be difficult to explain the chief advantage of wax candles compared with thofe of tallow. Oils, it fhould be confidered, do not take fire, unlefs they be previoufly volatilized by heat: and this is effected by means of the wick of a candle, or lamp. The oil rifes between the fibres of the wick by the capillary attraction. Heat, being applied to the extremity of the wick, volatilizes and fets fire to a portion of the oil. While this is diffipated by combuftion, another portion paffes along the fibres, or fupplies its place by becoming heated and burned likewife. In this way a conftant combuftion is maintained. A candle, how-

ever, differs from a lamp in one very eſſential circumſtance; viz. that the oil, or tallow, is liquefied only as it comes to be in the vicinity of the conflagration; and this fluid is retained in the hollow of the part, which is ſtill concrete, and forms a kind of cup. The wick, therefore, ſhould not, on this account, be too thin; becauſe if this were the caſe, it would not carry off the fluid as faſt as it becomes fuſed; and the conſequence would be, that it would run down the ſides of the candle: and as this inconvenience ariſes from the fuſibility of the oil, it is plain that a more fuſible candle will require a larger wick; or that the wick of a wax candle may be made thinner than that of one of tallow. The flame of a tallow candle will of courſe be yellow, ſmoky, and obſcure, except for a ſhort time after ſnuffing. When a candle with a thick wick is firſt lighted, and the wick ſnuffed ſhort, the flame is perfect and luminous, unleſs its diameter be very great; in which laſt caſe, there is an opake part in the middle, where the combuſtion is impeded for want of air. As the wick becomes longer, the interval between its upper extremity, and the apex of the flame is diminiſhed; and conſequently the oil, which iſſues from that extremity, having a leſs ſpace of ignition to paſs through, is leſs completely burned, and paſſes off partly in ſmoke. This evil increaſes, until at length the upper extremity of the wick projects beyond the flame and forms a ſupport for an accumulation of ſoot which is afforded by the imperfect combuſtion, and which retains its figure, until, by the deſcent of the flame, the external air can have acceſs to the upper extremity. But in this caſe, the requiſite combuſtion which might ſnuff it, is not effected; for the portion of oil emitted by the long wick is not only too large to be perfectly burned, but alſo carries off much of the heat of the flame, while it aſſumes the elaſtic ſtate. By this diminiſhed combuſtion, and increaſed efflux of half-decompoſed oil, a portion of coal or ſoot is depoſited on the upper part of the wick, which gradually accumulates, and at length aſſumes the appearance of a fungus. The candle does not then give more than one-tenth of the light which the due combuſtion of its materials would produce; and, on this account, tallow candles require continual ſnuffing. But if we direct our attention to a wax candle, we find that as its wick lengthens, the light indeed becomes leſs. The wick, however, being thin and flexible, does not long occupy its place in the centre of the flame; neither does it, even in that ſituation, enlarge the diameter of the flame, ſo as to prevent the acceſs of air to its internal part. When its length is too great for the vertical poſition, it bends on one ſide; and its extremity, coming in contact with air, is burned to aſhes; excepting ſuch a portion as is defended by the continual afflux of melted wax, which is volatilized, and completely burned, by the ſurrounding flame. Hence it appears, that the difficult fuſibility of wax renders it practicable to burn a large quantity of fluid by means of a ſmall wick; and that this ſmall wick, by turning on one ſide in conſequence of its flexibility, performs the operation of ſnuffing upon itſelf, in a much more accurate manner than it can ever be performed mechanically. From the above ſtatement it appears, that the important object to ſociety of rendering tallow candles equal to thoſe of wax, does not at all depend on the combuſtibility of the reſpective materials, but upon a mechanical advantage in the cup, which is afforded by the inferior degree of fuſibility in the wax: and that, in order to obtain this valuable object, one of the following effects muſt be produced: either the tallow muſt be burned in a lamp, to avoid the gradual progreſſion of the flame along the wick; or ſome means muſt be deviſed to enable the candle to ſnuff itſelf, as the wax-candle does; or the tallow itſelf muſt be rendered leſs fuſible by ſome chemical proceſs. With a view to the firſt of theſe objects, a cylindrical piece of tallow was inſerted into a metallic tube, the upper aperture of which was partly cloſed by a ring, and the central part occupied by a metallic piece nearly reſembling that part of the common lamp which carries the wick. This piece was provided with a ſhort wick. The cylinder of tallow was ſupported beneath in ſuch a manner that the metallic tube and other part of this lamp were left to reſt with their whole weight upon the tallow at the ring or contraction of the upper aperture. In this ſituation the lamp was lighted, and it burned for a conſiderable time with a bright clear flame, more uniformly intenſe than that of a candle, and ſuperior to the ordinary flame of a lamp in its colour and the perfect abſence of ſmell. After ſome minutes it began to decay, and ſoon afterwards went out. Upon examination it was found, that the metallic piece which covered the wick had fuſed a ſufficient quantity of tallow for the ſupply during the combuſtion; that part of this tallow had flowed beneath the ring, and to other remote parts of the apparatus, beyond the influence of the flame; in conſequence of which, the tube and the cylinder of tallow were faſtened together, and the expected progreſſion of ſupply prevented. In every lamp for burning conſiſtent oils, it ſeems probable, ſays Mr. Nicholſon (ubi infra,) that the materials ought to be ſo diſpoſed as to deſcend to the flame upon the principle of the fountain reſervoir. Although this conſtruction failed, a contrivance of a ſimilar nature would be of very great public utility. With regard to the ſecond object above ſpecified, Mr. Nicholſon is led by various conſiderations to imagine, that the ſpontaneous ſnuffing of candles made of tallow or other fuſible materials, will ſcarcely be effected but by the diſcovery of ſome material for the wick, which ſhall be voluminous enough to abſorb the tallow, and at the ſame time ſufficiently flexible to bend on one ſide. The moſt promiſing ſpeculation reſpecting this moſt uſeful article, ſeems to regard the cup which contains the melted tallow. This is apt to break down by fuſion, and thus to ſuffer its fluid contents to eſcape. The Chineſe have a kind of candle about half an inch in diameter, which, in the harbour of Canton, is called a "lobchock." The wick is of cotton, wrapped round a ſmall ſtick or match of the bamboo cane. The body of the candle is white tallow; but the external part to the thickneſs of about one thirtieth of an inch conſiſts of a waxy matter coloured red; this covering gives a conſiderable degree of ſolidity to the candle and prevents its guttering, becauſe it is leſs fuſible than the tallow itſelf. The ſtick in the middle might probably be of advantage in throwing up a leſs quantity of oil into the flame than would have been conveyed by a wick of cotton ſufficiently ſtout to have occupied its place unſupported in the axis of the candle. Mr. Nicholſon ſays that he formerly made a candle in imitation of the "lobchock." For this purpoſe he adapted the wick in the uſual pewter mould; he then poured in wax, which was immediately afterwards poured out; the film of wax, adhering to the inner ſurface of the mould, ſoon became cool; and the candle was completed by filling the mould with tallow. When it was drawn out, it was found to be cracked longitudinally on its ſurface, which he attributed to the contraction of the wax, by cooling, being greater than that of the tallow: or it might have been owing to the too ſudden cooling of the wax before the tallow was poured in. The experiment was not repeated. After all, the moſt deciſive remedy for the imperfection of this cheapeſt, and in other reſpects beſt material for candles, would undoubtedly be a diminution of its fuſibility: with this view Mr. Nicholſon made ſome experiments. The object is, in a commercial view, entitled to aſſiduous and extenſive inveſtigation. Chemiſts in general, ſuppoſe the hardneſs or leſs fuſibility of wax to ariſe from

oxygen; and to this object attention should be directed in the inquiry. Nicholson's First Principles of Chemistry, p. 517. Nicholson's Journal, Vol. I. p. 70.

The Chinese obtain from the tallow tree (*Croton sebiferum*, Linn.) a kind of vegetable fat, with which they make a considerable proportion of their candles; which are firmer than those of tallow, and free from all offensive odour; but they are not equal to those of wax, or spermaceti. Cheap candles are also made of tallow, and even of grease of too little consistence to be used, without the contrivance of being coated with the firmer substance of the tallow tree or of wax. The surface of these candles is sometimes painted red. Their wicks are made of different materials. For their lamps, they use the amianthus, which burns without being consumable in fire, or the artemisia, and carduus maræus, with which tinder is also made; but for candles, they use a light inflammable wood, in the lower extremity of which is pierced a small tube to receive an iron pin, which is fixed on the flat top of the candlestick, and thus supports the candle, without the necessity of a socket. The candle-makers at Munich have for several years past prepared tallow candles with wooden wicks, which afford about the same quantity of light as a wax candle, burn also with great steadiness and uniformity, and never crack or run. These wicks are formed of very thin slips of wood, bound round to a considerable thickness with very fine unspun cotton, but such that the size of the wick does not much exceed that of the wick of a common candle. The candle-makers either purchase or prepare for themselves these slips of wood, which are somewhat square and not completely rounded, and are made of pine, willow, and other kinds of wood, but most commonly of fir. Some take shoots of the pine-tree a year old, or common fir twigs of the same age, scrape off the bark, and reduce them to the size of a small straw; they then rub over these rods with wax or tallow, till they are covered with a thin coating of either of these substances; after which they roll them on a smooth table in a very fine carded cotton, drawn out to about the length of the rod or candle-mould. After this preparation the wick will have acquired the size of the barrel of a small quill; and the more accurately the size of the wick is adapted to that of the candle-mould, so much the clearer and longer will the candle burn. These wicks are then placed very exactly in the middle of the mould, and retained in that position; and good fresh tallow, previously melted with a little water, is then poured round them; but old and rancid tallow will not run if the wicks be properly made. These candles not only burn longer than the common ones, but they do not flare, and they are less prejudicial to the eyes of those who are accustomed to read or write at night. They must be snuffed with a pair of sharp sciffars, and in doing this care must be taken not to damage or break the wick.

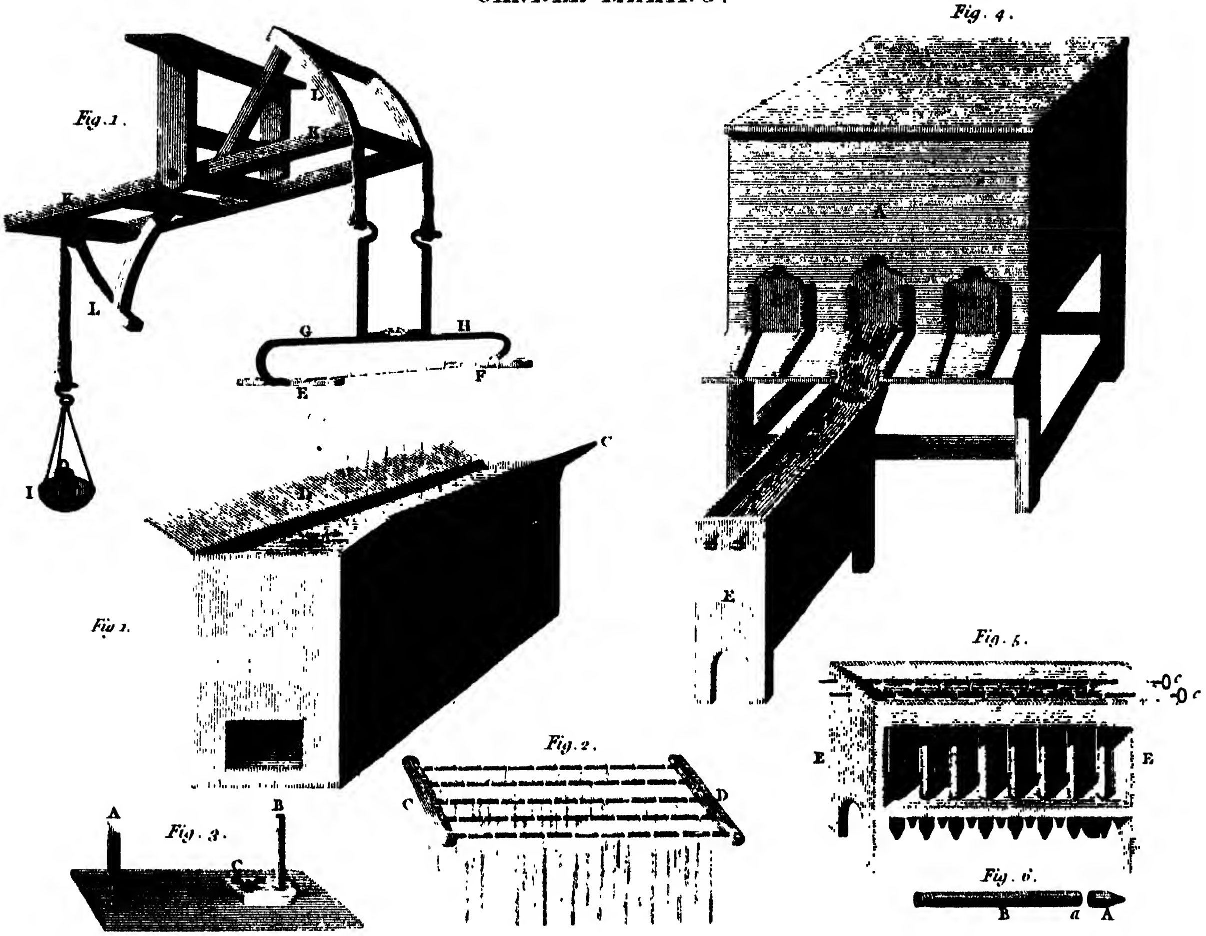
It has been suggested by Dr. Franklin, that the flame of two candles joined gives a much stronger light than both of them separate. Probably the union of the two flames produces a greater degree of heat, by which the vapour is attenuated, and the particles of which light consists more copiously emitted. Priestley's Hist. of Vision, &c. p. 807. For a comparison of the light of a candle with that of a lamp, see LAMP. For the method of estimating the intensity of candle-light, &c. see LIGHT and PHOTOMETER.

Dr. Ingenhousz has described in the Philosophical Transactions (vol. 68.) a method of lighting a candle by a small electrical spark. For this purpose he uses a small phial, having 8 or 10 inches of metallic coating, or even less, charged with electricity; and the operation may be performed at any time of the night by a person, who has an electrical machine in his room. "When I have occasion to light a candle," says he, "I charge a small coated phial, whose knob is bent outwards, so as to hang a little over the body of the phial; then I wrap some loose cotton over the extremity of a long brass pin or a wire, so as to stick moderately fast to its substance. I next roll this extremity of the pin wrapped up with cotton in some fine powder of resin, which I always keep in readiness upon the table for this purpose, either in a wide-mouthed phial or in a loose paper; this being done, I apply the extremity of the pin or wire to the external coating of the charged phial, and bring as quickly as possible the other extremity wrapped round with cotton to the knob; the powder of resin takes fire and communicates its flame to the cotton, and both together burn long enough to light a candle. As I do not want more than half a minute to light my candle in this way, I find it a readier method than kindling it by a flint and steel, or calling a servant. I have found, that powder of white or yellow resin lights easier than that of brown. The "farina lycopodii" may be used for the same purpose; but it is not so good as the powder of resin, because it does not take fire quite so readily, requiring a stronger spark not to miss; besides, it is soon burnt away. By dipping the cotton in oil of turpentine, the same effect may be as readily obtained, if you take a jar somewhat greater in size. This oil will inflame so much the readier if you strew a few fine particles of brass upon it. The pin dust is the best for this purpose; but as this oil is scattered about by the explosion, and when kindled fills the room with much more smoke than the powder of resin, I prefer the last."

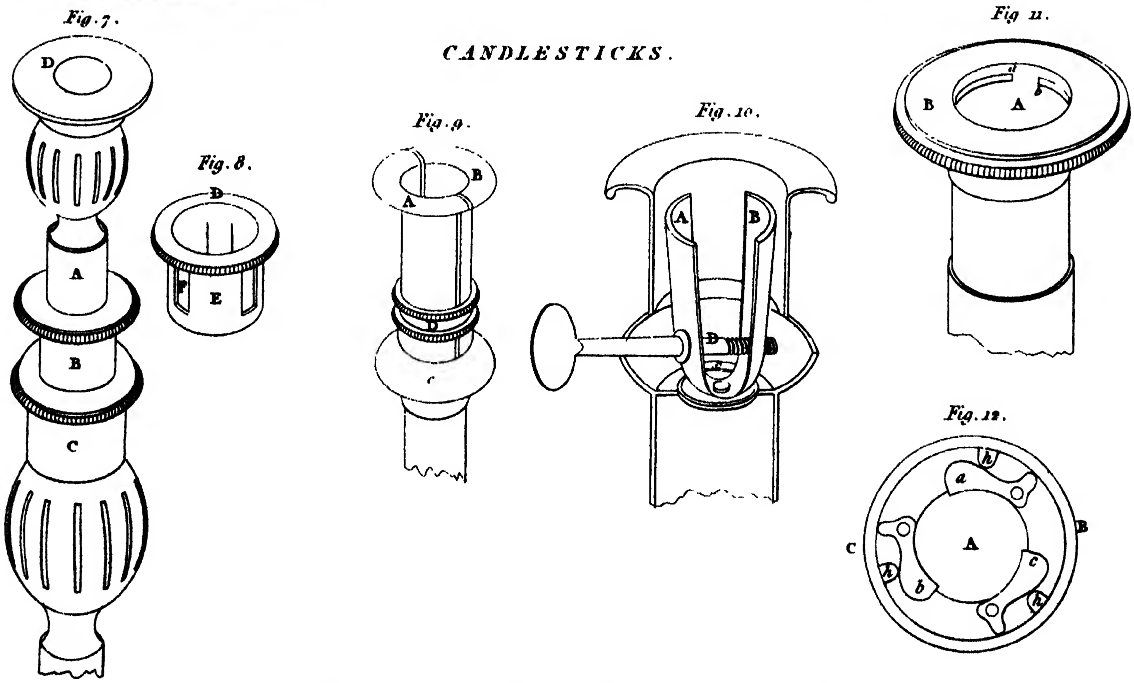
For the method of lighting candles by phosphoric tapers or matches, see PHOSPHORUS.

CANDLE.

CANDLE MAKING.



CANDLESTICKS.



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Carbon

CARBON, in *Chemistry*.

§ 1. *Of Carbon.*

This substance abounds largely in all vegetable and animal bodies, as well as in the mineral kingdom, yet it is of very rare occurrence in a state of absolute purity. When uncombined with any foreign matter, it is transparent, colourless, intensely hard, and crystallized; and, both on account of its beauty and value, is placed at the head of the gems under its commercial and mineralogical name DIAMOND.

Diamond was formerly supposed to be incombustible, and the first hint at its real nature was given by Newton. This philosopher having observed that inflammable bodies possess, in proportion to their density, a greater power of refracting the rays of light than any other substances, was induced to rank the diamond among them, on account of the eminent degree in which it possessed this property. This conjecture was verified, in 1691, by the members of the Academy del Cimento at Florence, who consumed several diamonds by placing them in the focus of a lens. Francis I. emperor of Germany, afterwards witnessed the destruction of several more by the heat of a furnace. These experiments were repeated by Macquer, Rouelle, Darcet, and Cadet, who ascertained, that by the concurring action of air and heat, diamond was not only evaporated, but actually burnt with flame; they also proved that when the air was excluded the highest heat of a furnace produced little or no effect on this substance.

In 1772, an experiment was made by Lavoisier, which may be considered as the first attempt to effect a chemical analysis of diamond. He burnt a few grains of this substance in a jar of common air, confined over mercury, by means of a very powerful lens, and found that the pure part of the air had disappeared, as well as a considerable proportion of the diamond, and that the residual air abounded with carbonic acid: repeating the same process only with the substitution of an equal weight of highly burnt charcoal, he found precisely analogous effects to take place, and therefore concluded that diamond and charcoal in their chemical essence were very similar to each other. In 1785, M. Morveau discovered that diamond, when dropped into melted nitre, burns like charcoal, and without leaving any residuum. This fact suggested to Mr. Tennant a method of analysing diamond, which was effected with complete success. Into a gold tube, closed at one end, and terminating at the other in a curved glass tube, were put a quarter of an ounce of nitre and $2\frac{1}{2}$ grains of diamonds; the tube was then kept at a full red heat for an hour and a half, and when its contents were afterwards examined, the diamonds were found to have entirely disappeared, and the nitre was changed into sub-carbonat of potash; to a solution of this salt muriat of lime was added, and thus the carbonic acid was transferred to the lime: from this carbonat of lime the carbonic acid was expelled by means of the muriatic acid, and was found to amount to 9.03 grains. Hence 27.6 parts of diamond and 72.4 of oxygen constitute 100 of carbonic acid. But, according to Lavoisier, 28 parts of charcoal, and 72 of oxygen constitute 100 of carbonic acid; therefore diamond and pure charcoal may be considered as chemically the same.

Morveau has since endeavoured to invalidate the experiment of Mr. Tennant, and to shew that diamond is pure carbon and that charcoal is an oxyd of carbon, but his experiment is so manifestly incorrect as to merit no sort of confidence.

A further proof of the analogy between charcoal and diamond is furnished by an ingenious experiment of Clouet's, in which

which fome pure bar iron being expofed to a high heat, in contact with diamond, this latter fubftance was found to have difappeared, and the iron to be converted into fteel.

But though diamond is the pureft form of carbon, yet its high value, its hardnefs, and denfity, forbid it to be ufed in ordinary chemical experiments; all the fucceeding facts, therefore, relate to that lefs pure kind of carbon which is obtained by expofing common Charcoal, or, ftill better, lamp-black, to a high heat in clofe veffels.

Carbon, or prepared charcoal, is an excellent conductor of galvanifm and electricity, but tranfmits caloric with very great difficulty; a fhort piece may be held by one end while it is heated red at the other, without conveying any notable warmth to the hand.

It is infoluble in water, and even the combined action of air and water produces hardly any perceptible effect upon it; hence it is that ftakes of wood that are charred on the outfide will laft much longer without rotting than the foundeft timber that has not undergone this preparation.

Charcoal is not fufible by the greateft heat that can be applied: if expofed to a very high temperature in clofe veffels it lofes little or nothing of its weight, but fhrinks in fize, and becomes proportionably more compact, denfe, and fonorous, and acquires a deep velvet black colour. But though charcoal is unalterable by mere heat, yet when heated red in the open air, it fpeedily undergoes combuftion, and is converted into Carbonic Acid; pure oxygen gas produces, as might be expected, a much more powerful effect on this fubftance than atmofpheric air does; a piece of charcoal barely heated at one end to rednefs and plunged into this gas, immediately burns with an intenfely white glow, and is rapidly changed into carbonic acid.

Water, although it is, as we have already mentioned, incapable of diffolving carbon, is yet very obftinately retained by it, partly on account of its porous texture, and in part probably on account of a ftrong mutual affinity fubfifting between them. When, however, charcoal is red hot, or nearly fo, it decompofes any water with which it may happen to be in contact, and unites with both the elements of this fubftance; producing with the oxygenous bafe, according as this is added to faturation or not, carbonic acid and carbonous oxyd; and with the hydrogenous bafe forming a heavy inflammable air, called carburetted hydrogen or hydrocarbonat.

Newly prepared charcoal is capable of abforbing various gaffes, with remarkable facility, and in confiderable proportions. This fact had been obferved by Fontana, Lametherie, Prieftley, Scheele, and Morveau, but the firft important feries of experiments on this fubject was publifhed by Morozzo, fince which time Meffrs. Rouppe and Van Noorden of Rotterdam have made a confiderable and very valuable addition of facts on this curious fubject. The charcoal for the experiment being highly ignited in an open fire, to expel all the moifture and gafeous fubftances which it may contain, is quickly removed, and extinguifhed by being plunged under mercury, or inclofed in an air-tight metallic box; when quite cool it produces the following effect on the various gaffes.

One part of charcoal is capable of abforbing three times its bulk of atmofpheric air in four or five hours; of oxygen gas there is abforbed, at firft rapidly, and afterwards more flowly, 2.8 times the bulk of the charcoal. Azot and hydrogen are taken up inftantaneoufly, but only in the proportion of 1.6 of the former, and 1.8 of the latter. Of nitrous gas 8.5 parts are very flowly, and of carbonic acid 14.3 parts are very rapidly abforbed. The gaffes thus taken up undergo no change except of form, nor are the refidues at all altered, and they may be all again feparated from the charcoal by diftillation, at the temperature of boiling water. If charcoal faturated with hydrogen in the way defcribed is introduced into oxygen gas, or even into atmofpheric air, a confiderable abforption of the oxygen takes place, and combines with the hydrogen, forming water, and at the fame time the temperature rifes to about 100° Fahr. The refult is the fame if the experiment is inverted, that is, if charcoal charged with oxygen is introduced into hydrogen gas. Charcoal faturated with hydrogen is even capable of decompofing nitrous gas, the oxygen being abforbed and the azot alone remaining in the elaftic ftate. Charcoal faturated with azot is alfo capable of decompofing atmofpherical air, by abftracting the oxygenous part, which is a remarkable proof how adverfe the gafeous ftate is to chemical combination.

Carbon is capable of combining with fulphur; the fubftance hence refulting is called carburetted fulphur, and almoft all that is known as yet concerning it is due to the united inveftigations of Clement and Deformes, two French chemifts. It is thus prepared. Fill an earthenware tube with fmall pieces and powder of newly burnt charcoal, fix it in a flanting direction in a furnace, and lute to the lower end a glafs tube, dipping it into fome water contained in a receiver. Faften a glafs tube alfo to the upper extremity of the earthen pipe, and fill it with fhort cylindrical pieces of fulphur, and fit a cork to the open end of the glafs tube with a moveable wire paffing through its centre, by which the pieces of fulphur may be pufhed at pleafure towards the earthen pipe. The apparatus being completed, heat the pipe very gradually, and as foon as the gas cafually contained in the charcoal is driven out, caufe the fulphur, by means of the wire, to approach the heated part of the apparatus. Allow it to remain at fuch a diftance that it may melt as flowly as poffible, and run down among the charcoal; and if thefe precautions are duly obferved, a yellowifh oily liquor will foon be perceived in the terminating glafs tube, which will drop into the water of the receiver, and collect at the bottom of the veffel, without at all uniting with the fupernatant fluid. The carburet of fulphur thus obtained is a tranfparent liquid, colourlefs when pure, but generally of a yellowifh-green tinge, and of a difagreeable flightly pungent odour, differing, entirely, however, from that of fulphuretted hydrogen. The fpecific gravity of carburetted fulphur is about 1.3. It evaporates in the air with nearly the fame rapidity as ether, and, like this fluid, finks the thermometer during the procefs in a remarkable degree. If it is put into an air-pump, and the atmofpherical preffure be reduced to about nine inches of mercury, the carburetted fulphur begins to affume the form of a gas; but upon reftoring the common preffure, this gas will immediately again refume its liquid ftate. It takes fire upon the application of a flame, and burns like alcohol, giving out at the fame time a fulphureous odour, and depofiting both fulphur and carbon. When kept for fome time in a vial with atmofpheric or azotic gaffes, it is diffolved by them in fmall proportion, and renders them inflammable. It combines with nitrous gas, and the mixture burns like zinc. When diffolved in oxygen gas, the refult is an air that explodes with fuch prodigious violence as to render it dangerous to fet fire to even a few ounce meafures at the fame time. In the ftate of vapour it combines flowly with the cauftic fixed alkalis, forming with them deep amber-coloured folutions. By alcohol it is reduced to a foft pafty confiftence. It diffolves very eafily in cold olive oil, or in ether, depofits a little charcoal, and then affumes a cryftalline form.

Carbon is faid by Prouft to be capable of uniting with

phoſphorus, but this, from ſubſequent experiments, appears to be a miſtake.

Two of the metals are known to unite with charcoal; when combined with Iron the product is called ſteel; and with Copper it forms a peculiar ſubſtance, firſt noticed by Dr. Prieſtley, and named by him charcoal of copper.

The action of the alkalies upon charcoal has been but little examined into; it is certain, however, that cauſtic potaſh, by long digeſtion with this ſubſtance, becomes coloured and partly carbonated.

The undecompoſable acids appear to have no action on charcoal, but the decompoſable ones are deprived by it of their oxygen, either entirely or in part, and the charcoal is changed into carbonic acid; thus phoſphoric acid and charcoal yield, by ignition, phoſphorus and carbonic acid; ſulphuric acid and charcoal yield ſulphur, ſulphureous acid, and carbonic acid. If highly dried and finely pulveriſed charcoal is poured into recently prepared oxymuriatic acid gas; as ſoon as the two ſubſtances come into contact the charcoal becomes red hot, and falls to the bottom of the veſſel, like a ſhower of fire.

The neutral and earthy ſalts with decompoſable acids are remarkably changed at a red heat by charcoal: the others ſuffer no perceptible alteration. Thus the ſulphats are converted into ſulphurets, the nitrats become carbonats, while the muriats and fluats remain unchanged.

The metallic ſalts are all of them decompoſed by charcoal at a greater or leſs degree of heat, in conſequence of the deoxygenation of their baſes, independently of the action of this ſubſtance on their acids.

The effects of charcoal in clarification are both curious and important. They were firſt noticed by M. Lowitz of Peterſburg, and have for the moſt part been amply confirmed by ſucceeding obſervers, although the preciſe cauſe of theſe remarkable changes has not been ſatisfactorily aſcertained. All that is eſſential for this purpoſe is, that the charcoal ſhould be in fine powder and very dry; hence the only preparation requiſite is to pulverize ſome well burnt common charcoal, and then heat it in a covered crucible to a glowing red, till it ceaſes to give out an inflammable vapour. If it is not employed immediately, it ought to be kept in a ground ſtoppered glaſs bottle, and may then be preſerved unimpaired for any length of time. The effects of this prepared charcoal are very ſtriking. Being mixed with common vinegar, or any kind of wine, a thick froth riſes to the ſurface, and the liquors, after filtration, are found to be as limpid as water. The filthieſt and moſt putrid ditch-water is in like manner rendered perfectly clear, inodorous and inſipid; and rancid oils are alſo deprived of their ſmell and taſte by repeated filtration through this prepared charcoal. Hence alſo its peculiar efficacy as a dentrifice; it is ſufficiently hard to remove the concretions from the teeth without injuring the enamel, while it neutralizes and entirely deſtroys for a time any fœtor which may ariſe from a carious tooth.

§ 2. *Of carbonous oxyd, or gaſſeous oxyd of carbon.*

Dr. Prieſtley was the firſt perſon who effectually called the attention of chemiſts to this ſubſtance; but for a correct acquaintance with its nature and properties we are indebted to Mr. Cruickſhank. It had always been objected by Dr. Prieſtley, againſt Lavoiſier's hypotheſis of the conſtitution of fixed air, that when charcoal, however dry, was diſtilled with ſcales of iron, or the red oxyd of mercury, the product was not only carbonic acid, but a large quantity of a heavy, inflammable air, reſembling, in many reſpects, carburetted hydrogen, and ſuppoſed by Dr. Prieſtley to be actually this very gas. Now carburetted hydrogen conſiſts of hydrogen, holding carbon in ſolution; and if it were really produced by the mutual action of carbon and a metallic oxyd, could only be accounted for upon the Lavoiſerian theory by the caſual preſence of ſome water. But the gas is produced in ſuch great abundance, even when the materials have ſeparately been firſt expoſed to a very high heat to drive off every atom of water, that this hypotheſis is untenable; it is, therefore, an obligation of no trifling kind that the modern chemical theory is under to Mr. Cruickſhank, for having ſhewn that this gas, though inflammable, does not neceſſarily contain any hydrogen whatever, but has only a ſimple combuſtible baſe, namely, carbon, and differs from carbonic acid merely by its ſmaller proportion of oxygen. Hence, it is properly called an oxyd of carbon, and bears the ſame analogy to carbonic acid as the nitrous oxyd does to the nitric acid. The experiments of Mr. Cruickſhank have been repeated with much apparent accuracy by Meſſrs. Clement and Deſormes, and the reſults obtained by them correſpond very nearly with thoſe of the former chemiſt.

The gaſſeous oxyd of carbon may be produced either by the partial oxygenation of carbon, or the partial deoxygenation of carbonic acid, or the ſolution of carbon in carbonic acid, on each of which methods we ſhall proceed to ſay a few words.

The original experiment by Dr. Prieſtley is the following. Equal parts of ſcales of iron and charcoal (each having previouſly been ignited in ſeparate veſſels), were put into a glazed earthen retort and ſtrongly heated. In a ſhort time a prodigious quantity of air came over, which, on examination, was found to conſiſt of one tenth carbonic acid, and the remainder was "an inflammable air of a very remarkable "kind, being quite as heavy as common air. The reaſon "of this," Dr. Prieſtley adds, "was very apparent, when "it was decompoſed by dephlogiſticated air, for the greater "part of it was fixed air." The above two important properties, namely, the weight of this gas and its almoſt total convertibility into carbonic acid by oxygen, are fully confirmed by ſubſequent experiments.

Mr. Cruickſhank, in repeating this experiment of Dr. Prieſtley, found, that as ſoon as the retort was red, abundance of gas came over, which, being examined at different periods, was found, in the beginning of the proceſs, to be compoſed of one part of carbonic acid and four of carbonous oxyd, with a ſmall admixture of carburetted hydrogen; after this, to the end of the proceſs, the proportion of carbonous oxyd gradually increaſed to about ſix-ſevenths of the whole. Two ounces of the materials afforded many gallons of the gas.

The ſublimed oxyd of zinc was next ſubſtituted to the iron ſcales, and diſtilled in the ſame manner with charcoal. Even before the retort became red much gas was given out, and, on increaſing the heat, it came over in torrents. It contained a much ſmaller proportion of carbonic acid than the former, and, towards the end, conſiſted of pure oxyd of carbon. Part of the zinc was found, in the metallic ſtate, ſublimed into the neck of the retort. In like manner litharge, the grey oxyd of manganeſe, and the red oxyd of copper, produced with charcoal, firſt, a mixture of carbonic acid with carbonous oxyd, and, at laſt, the inflammable gas in a ſtate of purity.

The diſtillation of charcoal and the ſublimed oxyd of zinc was repeated by Clement and Deſormes, with particular attention to the quantity of products from a given weight of materials. The charcoal and zinc were firſt heated ſeparately, and examined. Common charcoal, when heated ſtrongly, gave a conſiderable quantity of inflammable gas, and about $\frac{1}{10}$th of its weight of water. After an hour nothing further came over; ſo that, to enſure the purity of

the charcoal, it ſhould be uſed hot from the crucible or other veſſel in which it has been expoſed to a full red heat for half an hour. The oxyd of zinc gave out nothing at all by being heated *per ſe*; ſo that it may at any time be conſidered as pure, when previouſly free from accidental moiſture.

It was found, by experiment, that 14.36 parts of zinc increaſed, by calcination, to 17.48 of white ſublimed oxyd; and hence it is inferred that 100 parts of white oxyd conſiſt of 82.15 metal, and 17.85 oxygen. Pure charcoal, prepared as above, was mixed, to the amount of 30 grammes, (463 grains) with an equal weight of oxyd of zinc, which were put into a coated glaſs retort, communicating with lime-water, through which all the gaſeous products paſſed. When firſt heated, a ſmall portion of carbonic acid gas appeared, rendering the lime-water turbid; but this ſoon ceaſed, and the gas was purely inflammable. In five hours the production of gas had entirely terminated, and the total products of the operation were as follows:

	Grammes.
Zinc ſublimed in the retort	21.82
Charcoal remaining -	26.60
Carbonic acid	0.07
Nine litres (16.9 wine pints) of inflammable gas	10.35
	58.84
Loſs	1.16
	60.00

In all the preceding experiments the carbonous oxyd was obtained by the partial deoxygenation of the metallic oxyds and the conſequent oxygenation of the carbon. In thoſe which we are about to relate, the ſame gas was procured by inverting the proceſs, that is, by depriving carbonic acid of a portion of its oxygen.

Dr. Prieſtley, having obtained an inflammable gas, by heating together carbonat of barytes and magnetic oxyd of iron, Mr. Cruickſhank was induced to vary the experiment in the following manner. Equal parts of chalk (heated red hot previouſly for ten minutes), and of iron filings were mixed together, and heated in an earthen retort, abundance of gas was given out, conſiſting pretty uniformly of one part carbonic acid and five of carbonous oxyd.

An ounce of chalk previouſly heated red for ten minutes, was mixed with an equal weight of zinc filings, and heated gradually in a coated glaſs retort. A little carbonic acid came over at firſt, but mixed with oxyd of carbon; and when the contents of the retort were thoroughly red, nothing but the inflammable gas came over, and that in prodigious quantity. It was examined at different periods of the diſtillation, and proved to be wholly unmixed with carbonic acid. After the proceſs, the retort being examined, there was found ſome ſublimed oxyd of zinc in its neck, below which was ſome metallic zinc, and at the bottom was a mixture of oxyd of zinc, and partly cauſtic lime. Chalk, with tin filings, gave a ſimilar reſult.

In theſe experiments, the carbonic acid was united to an earthy baſe before diſtillation, and conſequently was expoſed to the deoxydating effect of the metallic filings in its naſcent ſtate, or, at the moment of its aſſuming the gaſeous form, a ſtate in which airs of all kinds are peculiarly ſuſceptible of chemical change. Mr. Cruickſhank found, however, that carbonic acid, even in the elaſtic ſtate, was alſo ſuſceptible of being deoxydated by the ſame means, though not quite ſo eaſily. For this purpoſe, ſome dry chalk was introduced into an iron retort, over which was rammed ſome dry ſand, and a ſtratum of iron-filings over all. In this arrangement, the carbonic acid gas expelled from the chalk had to traverſe a ſtratum of ſand three inches thick, before it could reach the iron-filings. The gaſeous products of the diſtillation were a quantity of undecompoſed carbonic acid, together with a large proportion of the inflammable gas, and the iron-filings were taken out conſiderably oxydated. The decompoſition of carbonic acid by metals does therefore take place, when the acid is in the gaſeous form, but by no means ſo perfectly as when in its naſcent ſtate. A ſimilar decompoſition was alſo effected by forcing the ſame carbonic acid gas ſucceſſively backwards and forwards through an iron tube, the middle of which was full of iron-filings, and kept red hot by a ſmall furnace placed beneath it. A bladder was tied to each end of the tube to receive the gas, and, by paſſing it twenty times ſlowly through the tube, two thirds of it were converted into inflammable gas.

It is obvious, that if to any baſe, already united with oxygen, we add a freſh portion of the baſe, it will have the ſame relative effect as abſtracting part of the oxygen; and this offers another mode of preparing carbonous oxyd, which has been ſucceſsfully practiſed by Meſſrs. Clement and Deſormes. Pelletier had previouſly diſcovered that though the native carbonat of barytes is ſcarcely calcinable, *per ſe*, in any fire, yet it will readily part with its acid by calcination, if previouſly ground to fine powder, and mixed with a little charcoal. The chemiſts above-mentioned, on repeating this experiment with three parts of carbonated barytes and one of charcoal, obtained a large quantity of gas, compoſed of about $\frac{5}{6}$ carbonous oxyd, and $\frac{1}{6}$ carbonic acid, and the barytes remaining in the retort was found to be quite cauſtic. Here, therefore, it is to be ſuppoſed, that the carbonic acid is ſuperſaturated with its own baſe, and thus rendered much more volatile than before.

A more direct combination of carbon with carbonic acid was alſo obtained by the two aſſociated chemiſts juſt mentioned, with preciſely the ſame apparatus as that uſed by Mr. Cruickſhank for paſſing carbonic acid gas over red hot iron, except that the tube was filled with pulverized charcoal inſtead of iron-filings. The firſt ſenſible effect produced on the gas was a conſiderable dilatation, excluſive of the mere expanſion by heat, and ariſing from the ſolution of a part of the heated charcoal in the gas as it paſſed over. After each experiment, by far the greater part of the carbonic acid was changed into the inflammable gaſeous oxyd of carbon, the reſidual carbonic acid not amounting to more than from $\frac{1}{10}$th to $\frac{1}{30}$th of the whole. The remaining charcoal being taken out and weighed was found to be conſiderably diminiſhed; but the proportional loſs was uniformly greater in tubes of iron, than of glaſs or porcelain, doubtleſs on account of part of the carbon being combined with the iron, and thus converting it internally into ſteel. The compoſition of the gaſeous oxyd, into which the carbonic acid was changed, calculated from the amount of charcoal taken up by it in porcelain tubes, appears to be about 53 of oxygen, and 47 of carbon.

The properties of pure carbonous oxyd, prepared from chalk or carbonat of barytes, and filings of iron or zinc, are the following. It is lighter than atmoſpheric air, in the proportion of 22 to 23. Hence, its ſpecific gravity (that of water being 1000), will be 1.177, while that of atmoſpheric air is 1.2308; hence, it materially differs from carburetted hydrogen, the weight of which is not more than half that of common air. It ſuddenly deſtroys animal life.

It is in no degree altered by being electrized, *per se*, for a considerable length of time. It burns in the open air with a quiet, blue flame. When previously mixed with common air and kindled, it does not explode but burns slowly: when mixed with oxygen gas, and fired by the electric spark it explodes, but not very violently, and gives out a red flame. If a small jet, communicating with a reservoir of this gas, be set fire to, and introduced into a large balloon receiver filled with oxygen gas, it is found to burn brightly for a time, and afterwards goes out. The gas remaining in the receiver is not greatly diminished, and the inside of the vessel, though somewhat damp, is by no means studded with those visible drops of liquid that characterize the combustion of hydrogen. The residual gas, on examination, will be found to consist of carbonic acid with some uncombined oxygen.

The relative proportions of carbonous oxyd and oxygen requisite to mutual saturation, and the consequent production of carbonic acid, are the means of ascertaining the exact constituent parts of this inflammable gas. When 20 measures of pure gaseous oxyd are mixed with eight measures of oxygen and exploded, the whole is reduced to 18 or 19 measures, and is entirely absorbable by lime-water; it is, therefore, carbonic acid. The weight also of this latter product is found to correspond, as nearly as can be expected in experiments of this kind, with the sum of the weight of its two ingredients before mixture. One hundred cubic inches of carbonous oxyd with 40 inches of oxygen produce 92 cubic inches of carbonic acid, and the weight of the first may be estimated at 30 grains, of the second at 13.6, and of the third at 43.2; the sum of the two first differing from the third only by 0.4 of a grain.

Hence it may be inferred, that 100 parts, by measure, of gaseous oxyd of carbon, require for saturation 40 measures of oxygen gas, and produce, by combustion, about 92 measures of carbonic acid gas; or, by weight, that 100 grains of carbonous oxyd require about 45.5 grains of oxygen, and are converted into 144 grains of carbonic acid, 1.5 grain being allowed for water and casual impurities. Now carbonic acid has been found by Lavoisier and other chemists to consist of 28 parts, by weight of carbon, and 72 of oxygen; consequently 144 grains of carbonic acid (the product of the full oxygenation of 100 grains of the inflammable gas), contain 40.32 grains of carbon; therefore the remainder of the 100 grains of the oxyd, i. e. 59.68 grains, must be oxygen. Hence, carbonous oxyd may be stated as composed of

40.32	carbon
59.68	oxygen
100.00	

Or, by another calculation, 144 grains of carbonic acid contain 72 per cent., or 103.68 grains of oxygen; but only 45.33 grains of oxygen were added to the inflammable gas to produce this carbonic acid, and, consequently, the difference between 103.68 and 45.33, or 58.35 grains of oxygen were already contained in the gas, leaving 41.65 grains, to complete the 100 grains of this gas, for carbon: hence, according to this calculation, carbonous oxyd consists of

41.65	carbon
58.35	oxygen
100.00	

We may, therfore, reckon on an average, that 100 grains of carbonous oxyd, obtained from the decomposition of the earthy carbonats by metallic substances in its purest possible state, unmixed with any hydrogen, are composed of about 41 of carbon and 59 of oxygen.

A true combustion of the gaseous oxyd of carbon takes place when it is mixed with oxymuriatic acid gas. If the latter be recently made and added to carbonous oxyd in due proportion, the whole mixture is converted into carbonic acid and simple muriatic acid; the carbonous oxyd having been fully oxygenated by the excess of oxygen in the oxymuriatic acid. The proper proportions for the complete success of this experiment are two measures of carbonous oxyd, and 2¼ measures of oxymuriatic acid. A mixture, thus proportioned, being kept for 24 hours in a ground stoppered vial, and, for further security, inverted in mercury, when opened in water will undergo an instantaneous absorption of about two-thirds, which is muriatic acid gas; the residue, by agitation with lime-water, will be taken up, with the exception of about $\frac{1}{18}$th, which is a casual mixture of azot.

Oxyd of carbon, when heated with phosphorus, dissolves a portion, and then burns with a pale yellow flame. The phosphorus is neither deposited nor acidified by long standing, even when assisted by water.

The effect of hydrogen on the carbonous oxyd is very striking. When equal parts of these gasses are mixed together and passed through a glass tube made red hot, a complete decomposition takes place, the gaseous oxyd deposits its charcoal on the inside of the tube, which, being nearly melting, causes it to adhere, and to form a brilliant, uniform, black enamel; while the oxygen of the gaseous oxyd by union with the hydrogen forms water, which is condensed at the further end of the tube. Some of the hydrogen passes through apparently unaltered.

The decomposition of carbonic acid gas, by means of electricity, when in contact with mercury or any other easily oxydable metallic body, well illustrates the nature of carbonous oxyd. Dr. Priestley was the first who found a change to take place in carbonic acid gas by taking the electric spark in it repeatedly for a considerable time. Out of many experiments, the following may be selected. In a small tube containing about $\frac{1}{15}$th of an ounce measure of carbonic acid, and standing over mercury, the electric spark was taken for the space of an hour; after which the whole tube was clouded by a pulverulent matter of a black colour in the upper part of the tube, but yellow at the bottom, like sulphur. This substance, on examination, proved to be oxyd of mercury. The air itself was a little enlarged, and about a fifth part of it was rendered insoluble in water.

The elegant experiments of Th. de Saussure have thrown much light on this subject. Electric sparks were taken for 18 hours in a glass tube containing 13 cubic inches of dry and pure carbonic acid gas and confined by mercury. After electrization much black oxyd of mercury was discovered; a very slight dilatation amounting to no more than $\frac{1}{10}$th of a cubic inch was observed. On throwing up some caustic alkali no more than one cubic inch was absorbed, which was therefore carbonic acid; the next was very pure oxyd of carbon, for where 100 parts of it were burnt with about a third of oxygen gas no water was perceived, the product being merely carbonic acid.

Carbonic acid has also been decomposed by the same ingenious chemist by hydrogen, by aid of the electric spark. In a long glass tube were mixed together 3¾ measures of pure carbonic acid with an equal quantity of hydrogen, and the whole was electrized for twelve hours. A condensation

took place, confiderable at firft, but very trifling towards the conclufion of the procefs. A number of fine drops of water were depofited on the upper part of the tube, and the gafeous mixture was reduced in bulk from $7\frac{1}{2}$ meafures to $4\frac{3}{4}$, of which one was undecompofed carbonic acid, and the remaining $3\frac{3}{4}$ were carbonous oxyd, containing a fmall admixture of hydrogen. In the above experiment the hydrogen appears to unite with part of the oxygen of the carbonic acid, to form the water, which is condenfed, while the carbonic acid, by lofing oxygen, paffes to the ftate of carbonous oxyd.

A fimilar decompofition of carbonic acid by hydrogen alfo takes place when the mixed gaffes are paffed through a red hot porcelain tube, and the gafeous oxyd is produced.

§ 3. *Of hydrocarbonat, or carburetted hydrogen.*

In the former fection we have treated of the combination of carbon with a lefs portion of oxygen than is required for its acidification; in the prefent fection we fhall examine the phenomena attending the combination of carbon with hydrogen. Carburetted hydrogen, otherwife called *heavy imflammable air*, is an inflammable gas confiderably heavier than hydrogen, but lighter than carbonous oxyd, or common air: it does not render lime-water turbid, when agitated with it, and by combuftion with oxygen is totally refolvable into carbonic acid and water.

Before it was fufpected that carbon could exift in any other ftate of oxygenation than carbonic acid, it might be inferred, with tolerable though not abfolute certainty, that when any gas had been purified from carbonic acid by means of alkali or lime-water, if it furnifhed a frefh portion of this acid after combuftion with oxygen, the carbonaceous ingredient exifted in the ftate of pure carbon or charcoal. Therefore, as the only products of carburetted hydrogen, when burnt with oxygen, are carbonic acid and water, chemifts generally fatisfied themfelves with eftimating the quantity of carbon contained in the gas, by taking about 28 per cent. of the carbonic acid produced, and fet down the entire remainder as hydrogen. For example, if 100 cubic inches of any gas, weighing 15 grains, were totally refolvable into carbonic acid and water, by combuftion with oxygen; and if, by the combuftion, 54 inches of carbonic acid, weighing 25 grains, were produced, the quantity of carbon originally contained in the gas would be reckoned to be feven grains, (being 28 per cent. of the weight of the carbonic acid.) and the difference between 7 and 15, or eight grains would be confidered as the weight of the hydrogen; or, in other words, the gas would be called a carburetted hydrogen, confifting of hydrogen holding carbon in folution, in the proportion of eight, by weight, to feven of the latter.

But, it is obvious, that this mode of eftimating muft be totally erroneous in the cafe (probably very frequent), of a mixture of gafeous oxyd of carbon and hydrogen gas; and hence no approach to analyfis can be obtained without afcertaining both the water and carbonic acid produced, and even then various caufes of uncertainty will occur.

So that it is poffible, and by no means improbable, that there may exift three fpecies of gaffes, all of which have a claim to the title of hydrocarbonat, or carburetted hydrogen, namely, 1ft. hydrogen, fimply holding carbon in folution, or what correfponds with the original idea of a hydrocarbonate; 2d. hydrogen mixed with gafeous oxyd of carbon; 3d. a mixture of the two former fpecies, or hydrogen and gafeous oxyd of carbon with an excefs of carbon held in folution by one or both of thefe gaffes.

Carburetted hyrogen is obtained in a great variety of ways, and with very confiderable differences in fpecific gravity and the proportion of ingredients. It is found native on the furface of ftagnant waters, marfhes, wet ditches, &c. through which, if examined clofely, large bubbles will be feen to rife in hot weather, and may be increafed at pleafure by ftirring up the bottom with a ftick. In clofe, ftill evenings, if a candle be held over the furface, flafhes of a blue lambent flame may be perceived fpreading to a confiderable diftance. All that is not fabulous in the *ignis fatuus* is probably derived from this fource. This fpecies may be termed, for diftinction, the carburetted hydrogen of marfhes: in the pureft form in which it can be collected it is ufually mixed with about 20 per cent. of azot.

This gas is alfo given given out very abundantly by almoft every vegetable fubftance that is expofed to a dry heat fufficient for its decompofition. When heated in clofe veffels much more hydrocarbonat is obtained than by combuftion in the open air, the product in this latter cafe containing more carbonic acid. It would be endlefs to enumerate the vegetable fources of this gas, but we fhall mention fome of the moft convenient modes of obtaining it in a ftate of purity.

One of the commoneft methods employed is the deftructive diftillation of the acetous falts. For this purpofe, let a fmall proportion of dry acetite of potafh be heated in a glafs retort. The falt foon melts in its water of cryftallization, puffs up, and, if the retort is too fmall, is very apt to come over into the neck. The firft products are water and the air of the veffels; but, when the acetous acid begins to be fcorched, a large ftream of gas begins, and continues till the whole is red hot, and little elfe remains in the retort but carbonated alkali and a little charcoal. Along with the gas there arifes much oil, which is condenfed in the cool receiver. The gas, according to the analyfis of it by Dr. Higgins, after the firft portions have paffed over, confifts of nothing but hydrocarbonat and carbonic acid, which laft may be feparated by lime-water. The hydrocarbonat itfelf varies confiderably. The firft part is much heavier than the laft, (though ftill lighter than common air,) and appears to hold in folution part of the oil; for, on ftanding fome time over water, it becomes lighter, and is found to require lefs oxygen for faturation than before. The average fpecific gravity of the firft and laft gas mixed is to that of common air as two to three.

Carburetted hydrogen is obtained in great purity by fending the vapour of imflammable vegetable matter through an earthen or glafs tube paffing through a furnace, and kept red hot in the middle. The vapour of camphor, ether, alcohol, and other inflammables thus treated, is converted into this gas, but with much difference in quantity, according to the degree of heat and other circumftances.

Another method of obtaining carburetted hydrogen, is to put coal, wood, peat, &c. into any convenient veffel, an earthen or iron retort for example, and heat it flowly to rednefs.

Moft animal inflammable fubftances, fuch as filk, fat, wax, and the like, yield this gas as freely as vegetable matter, by a fimilar treatment. This was difcovered by Berthollet, in his mafterly refearches on the nature of animal matter and ammonia.

Carburetted hydrogen (or at leaft a gas that gives water and carbonic acid by combuftion with oxygen), is alfo generated in abundance, when charcoal, without previous drying, is heated *per fe* in clofe veffels, and continues to be given off till the charcoal has been in a ftate of full ignition for about an hour; after which it ceafes, and the charcoal, as already mentioned, is rendered pure. A fimilar procefs of obtaining

this gas, is to inclofe powdered charcoal in a tube paffing through a furnace, to confine the charcoal by a pellet of clay loofely fixed at each extremity of the tube, and in that fituation to fend through it the vapour of water kept boiling in a fmall retort attached to one end of the tube. Much carbonic acid gas is generated this way, and, when this is feparated by lime-water, the refidue is inflammable.

Laftly, this gas may be procured by the direct union of its conftituent parts. If hydrogen gas is paffed feven or eight times fucceffively through an iron tube containing charcoal, and heated red hot, a diminution of bulk takes place, the hydrogen diffolves a portion of the charcoal, and then affumes the properties of carburetted hydrogen.

A curious variety of hydrocarbonous gas, was difcovered by the affociated Dutch chemifts (Van Dieman, Trooftwyck, and others) which is procured from ether or alcohol, and has the remarkable property of generating an oil when mixed with oxymuriatic acid gas. Hence it has been termed *oily carburetted hydrogen*, or *olefiant gas*. The mode of preparing this fingular gas, and the enumeration of its diftinguifhing properties, will form the fubject of the next fection; it may, however, be obferved here, that according to Mr. W. Henry's experiments, the olefiant gas appears alfo to be contained in part in the hydrocarbonat from coal, wax, and fome other fubftances, and greatly to contribute to the quantity of light and heat which thefe gaffes give out as well as to their large proportion of carbonic acid.

Carburetted hydrogen is fingularly affected by the electric fpark. Dr. Auftin found, that on taking the electric fpark repeatedly through this gas, obtained from acetite of potafh, the bulk of the gas enlarged after every fhock, and at length expanded to nearly twice its original dimenfions. When examined after this expanfion, it was found to be as inflammable as before, and judging from the teft of lime-water no carbonic acid appeared to have been generated. Dr. A. concludes that the enlargement can only be owing to the production of a quantity of hydrogen, and makes fome inferences which, however, have fince been fhewn by Mr. W. Henry to be erroneous. Mr. H. demonftrates that there is no deftruction of carbon by this procefs, fince the fame quantity of carbonic acid is produced after as before electrization by the action of oxygen gas. He likewife makes it appear probable, that the water held in folution by the gas is the chief agent in its expanfion, fince when the gas has been dried by cauftic alkali no continuance of electrization will enlarge it more than one fixth of its original bulk; but when the contact of water is admitted, the bulk is doubled by the fame treatment. Perhaps the difcovery of carbonous oxyd will explain this fact. It is not improbable that the carbon of the gas may unite with the oxygen of the water, and thus produce the carbonous oxyd which would not give any precipitate with lime-water, and the bulk of the gas would be enlarged both by the carbonous oxyd and the hydrogen of the water, as well as by the expanfion which the hydrocarbonat would undergo after the carbon was feparated from it, whilft the actual quantity of carbon remaining the fame, as much carbonic acid would be feparated by compleat oxygenation as before electrization. It is not improbable that the affinities of hydrogen and carbon for oxygen are fo nearly equal, that either fubftance is able *partially* to decompofe the complete oxyd of the other. Thus we find, that when hydrogen and carbonic acid are together fubjected to electricity, the carbonic acid is partially decompofed, and the product is carbonous oxyd and water, and on the other hand, when water is decompofed by red hot charcoal, a part of the product is alfo the carbonous oxyd.

All the hydrocarbonats are fatal to animal life; not as appears from the mere abfence of oxygen, but from the prefence of fomething pofitively noxious: fince animals immerfed in it die fooner than they would from the mere interruption of refpiration.

This gas is fcarcely if at all abforbed by water, but by long ftanding over it depofits a part of its carbon. This, however, applies only to thofe hydrocarbonats that require at leaft their own bulk of oxygen to faturate them, and efpecially to that variety called olefiant gas.

Simple carburetted hydrogen, when fet fire to, burns at the furface in contact with the air with a blue flame with red edges, but when mixed with any of the olefiant gas the flame becomes much more brilliant, refembling that of oil. When applied to the purpofes of illumination the hydrocarbonat from coal, from lamp-oil, or from wax, produces as much light in an Argand lamp as oil in fubftance does; this appears to be owing to the olefiant gas which they contain. The brightnefs of the flame is much diminifhed when thefe gaffes have been kept over water, and hence for illumination they fhould be ufed as foon as prepared.

The combuftion of hydrocarbonat is much more brilliant in oxygen gas, and the products if a fufficient quantity of oxygen has been ufed, are merely water and carbonic acid.

If any of the hydrocarbonats be mixed with oxygen gas and fired in a clofe veffel by the electric fpark, or in any other way, an explofion takes place more or lefs violent according to the quantity of carbon contained in the gas, and the refult of the decompofition is carbonic acid, together with any unconfumed gas or excefs of oxygen, while the water is found condenfed in drops on the fides of the jar. A fingle cubic inch of the mixed airs is generally as much as can be conveniently managed at each explofion, and when any olefiant gas is prefent even this fmall quantity will endanger very thick glafs jars; a very vivid red flame appears at the moment of explofion, and a great inftantaneous enlargement takes place, after which the bulk is fuddenly reduced to much lefs than its original quantity. When the carbonic acid is abforbed, if the gaffes have been properly proportioned, no gafeous refidue is left except accidental impurities.

The oxymuriatic acid furnifhes alfo a very ufeful method of decompofing and analyfing all the hydrocarbonats. Mr. Cruickfhank's beautiful and accurate experiments on this fubject are highly inftructive. The oxymuriatic acid gas was procured from oxymuriat of potafh, by means of muriatic acid, and was ufed foon after being prepared, as it is in fome degree altered by keeping.

Pure hydrogen and oxymuriatic acid gas were firft tried; one meafure of the former with two of the latter mixed in a glafs vial with a ground ftopper, and inverted over water were fuffered to remain 24 hours. The ftopper being then withdrawn, the water rufhed into the vial, abforbing the whole of its gafeous contents, except about $\frac{1}{30}$ of the whole, which was azot, and doubtlefs a cafual impurity.

The different hydrocarbonats were then tried. In a bottle filled with, and inverted over water, one meafure of well wafhed hydrocarbonat from camphor was mixed with two of oxymuriatic acid. A flight cloud and trifling abforption were perceived at the time of mixture, after which the ftopper was put in, and the whole was left at reft for 24 hours. When opened under water all the gas was abforbed, except 0.43 of a meafure, and this was reduced by lime-water to 0.34. This refidue was ftill inflammable, but burnt with a lambent blue flame like carbonous oxyd; and

this it was proved for the most part to consist of, by the large quantity of carbonic acid which it yielded when fired with oxygen; two parts of it with one of oxygen yielding no less than 1.7 of carbonic acid.

In the above experiment the mutual decomposition of the oxymuriatic acid and carburetted hydrogen, produces no less than four new compounds: namely, common muriatic acid by the loss of oxygen; water by the union of oxygen with hydrogen; carbonous oxyd by the partial oxygenation of some of the carbon; and carbonic acid by the compleat oxygenation of the remainder.

On increasing the quantity of oxymuriatic acid to about four times that of the carburetted hydrogen, the whole of the carbon was now found to be completely oxygenated, and every thing was absorbed by water or lime-water; the products were therefore only muriatic and carbonic acids and water.

Mr. Cruickshank found a very considerable difference in the quantity of carbonic acid produced, and of course in the carbonaceous ingredient in the hydrocarbonats from camphor, ether, and alcohol, when they had been long kept over water or agitated with it. A similar difference in the quantity of combustible matter was observed by Dr. Higgins, in the hydrocarbonat from acetite of potash, which renders it highly probable that these hydrocarbonats hold in solution somewhat of an oily ethereal vapour, or a portion of true olefiant gas which water will absorb. This also, it probably is, which causes the slight diminution which some of the hydrocarbonats *immediately* experience when mixed with oxymuriatic acid gas; for with pure olefiant gas the diminution is great and immediate, as we shall presently mention. When oxymuriatic acid gas and carburetted hydrogen are mixed in the proportion of two of the former to one of the latter, and the mixture is exploded by the electric spark, a copious deposition of charcoal takes place, but when oxymuriatic acid gas is used in a larger quantity, the whole of the carbon is converted into carbonic acid. This separation of charcoal takes place only with the hydrocarbonats from camphor, ether, and alcohol, and even in these this property is lost by being kept some time over water.

Carburetted hydrogen is also readily decomposed by sulphur; the carbon being precipitated in form of a black powder, and the hydrogen uniting by preference with the sulphur forming hepatic gas. This may be most conveniently effected by making sulphur red hot in an earthen tube and then passing the carburetted hydrogen through it.

§ 4. *Of olefiant gas.*

The discovery of this singular species of carburetted hydrogen is due to some associated chemists of Amsterdam, (Van Dieman, Van Trooftwyck, Bondt, and Lawrenburgh,) and originated in their examination of the different products of the distillation of sulphuric acid and alcohol, in the preparation of ether. In the common process this gas appears towards the latter end of the distillation accompanied by the *oil of wine*; but in order to procure it immediately, for the purpose of experiment, nothing more is necessary than to put into a proof bottle a little rectified alcohol, and four times its weight of strong sulphuric acid; much heat is given out on mixture; the colour becomes first brown, and then black, and on the application of a gentle heat the gas in question is produced in vast abundance, and may be collected in jars inverted over water. The only foreign matters with which the gas is mixed are sulphureous acid, and a little ether, but these may be got rid of by washing it with some very dilute liquid ammonia, and then the olefiant gas remains pure.

When thus prepared it exhibits the following properties. Its specific gravity is to that of atmospheric air, as 905 to 1000. Its odour is very fetid. It burns with a dense flame, like an oil or resin. It is not absorbed nor altered by water, nor is it affected by any of the common reagents, whether gasses, alkalies, or acids, except the oxymuriatic acid gas. Equal parts of these gasses being mixed together, an immediate diminution of bulk takes place, a visible vapour fills the vessel, much heat is given out so as to be very sensible even to the hand, and at the same time a thick pearl-coloured oil appears in drops on the surface of the water, over which the mixture is made, and immediately sinks to the bottom.

It is from this singular production of dense oil, with the oxymuriatic acid, that this species of carburetted hydrogen has acquired the name of *olefiant* or *oil making*. When these two gasses are mixed in the proportion of four of oxymuriatic acid to three of carburetted hydrogen, the whole is absorbed, except accidental impurities.

The oil thus generated is heavier than water, whitish, and semi-transparent. By keeping it becomes yellow and limpid; its odour is highly fragrant and penetrating; its taste is somewhat sweet. It is sparingly soluble in water, to which it communicates its peculiar odour. Caustic potash has no effect on the oil, but separates the adhering muriatic acid and renders it more fragrant.

The constituent parts of olefiant gas appear to be only carbon and hydrogen, but it contains a larger proportion of the former than the common hydrocarbonats do. It is decomposed by sulphur like the other hydrocarbonats.

The combustion of this gas offers some curious circumstances. When an Argand lamp is supplied with it instead of oil, the flame far exceeds every oil and hydrocarbonat in beauty and brilliance. When mixed with oxygen gas, and detonated by the electric spark, the explosion is much more violent than that of common carburetted hydrogen. Mr. Henry found that a strong glass tube was shattered with only 0.3 of a cubic inch of olefiant gas, and 0.17 of oxygen; but when the quantity of oxygen is considerably below that required, for the compleat saturation of this gas, only a very trifling explosion is produced.

Another singular property of olefiant gas is the copious deposition of charcoal, when it is mixed with a small quantity of oxygen or oxymuriatic acid gas and kindled. After the mixture of the olefiant and oxymuriatic acid gasses, two or three minutes elapse before the oil thus generated is entirely precipitated, but if this mixture is immediately set fire to there is no production of oil; but in its stead so copious a deposition of charcoal takes place, that the whole vessel is obscured, as if it had been lined with lamp-black.

A similar deposition of carbon takes place when the olefiant gas is mixed with just enough of oxygen to begin the combustion. If two parts of the latter are mixed with $1\frac{1}{2}$ of the former, and the mixture set fire to by the electric spark, a copious deposition of carbon ensues.

The great excess of carbon contained in olefiant gas is also manifest from the large proportion of oxygen required for its saturation, amounting to 2.84 to one, estimating each by bulk.

Olefiant gas has also been procured by the Dutch chemists, above named, not only from alcohol and sulphuric acid, but by passing the vapour of alcohol or ether through a red hot earthen tube. In this case, however, the olefiant gas appears to be mixed with a little carburetted hydrogen. It is remarkable, that if a glass tube be used instead of an earthen one, the gas is no longer olefiant, but only simple carburetted hydrogen; but if the glass tube is filled with

either alumine or filex the fame effect is produced as with the earthen tube; on the other hand, when lime either pure or carbonated, or magnefia, were fubftituted to the two other earths, the gas was common carburetted hydrogen.

The whole of this very interefting part of chemiftry requires further examination, efpecially as far as regards the formation of carbonous oxyd.

Carbon, in reference to *Hufbandry* and *Gardening*, a matter obtained from different animal and vegetable fubftances, by means of a flow and confined combuftion. This fubftance is charcoal in its pure ftate; that which is commonly met with containing a portion of incombuftible earth, and fome faline matter in union with the carbon. See Carbon and Charcoal.

The author of the "Philofophy of Agriculture and Gardening," remarks, "that when animal and vegetable bodies are burnt without the accefs of air, that is, where their volatile parts are fublimed, there remains a greater quantity of charcoal, a much greater in vegetable bodies than in animal ones. This is termed carbon by the French fchool, when it is quite pure, and is now known to be one of the moft univerfal materials of nature: and as vegetable bodies contain fo much of it in their own compofition, they may be fuppofed to abforb it entire where they grow vigoroufly, efpecially as it is a fimple material: but they may poffibly form it alfo from water and air within their own veffels, when they are excluded from accefs to it externally. The whole atmofphere contains always a quantity of it in the form of carbonic acid, or fixed air; as is known by the fcum which prefently becomes vifible on lime water when expofed to the air, and which confifts of a reunion of the lime with the carbonic acid, which may therefore be faid to encompafs the earth. The fimplicity of carbon as an elementary fubftance was difputed by Dr. Auftin, who believed he had decompounded it. But Mr. Henry, by accurately repeating his experiments, has fhown the fallacy or inconclufivenefs of them, as may be feen in the Philofophical Tranfactions for 1797. And it is added that a further great refervoir of carbon exifts in lime-ftone, in the form of carbonic acid; which when the ftronger acid is poured on, the calcareous earth becomes a gas, acquiring its neceffary addition of heat from that which is given out in the combination of the ftronger acid with the lime. It alfo acquires its neceffary heat when lime-ftone is burnt, from the confuming fuel, rifing in the form of gas, and is diffipated in the air; and probably foon fettles on the earth as it cools, as it is confiderably heavier than the common atmofphere. But the great fource of carbon exifts in the black earth which has been lately left by the decompofition of vegetable and animal bodies; and is then in a ftate fit to combine with azote or nitrogen, and with oxygen, when expofed to thofe two gaffes, as they exift in the atmofphere, and is thus adapted either to promote the generation of nitrous acid, or to form carbonic acid, and thus to affift vegetation. Moraffes confift principally of the carbonic recrements of vegetable matters, which are gradually decompofed in great length of time into clay, with argillaceous fand, fuch as is found over coal beds, and fome calcareous earth, as in marl, and laftly, with fome iron and foffile coal. Thefe by elutriation are feparated from each other, and form the ftrata of coal countries. In other places they remain intermixed, as they were probably produced from the decompofition of vegetables and terreftrial animals; and form what in books of practical agriculture is called a *loamy* foil, confifting of carbonic matter, fand, and clay, with a portion of iron. It has always been obferved, that this black garden mould, or earth produced from the recrements of vegetables, is capable of abforbing a much greater quantity of putrid effluvia than either air or water, and probably of combining with its ammonia, and producing a kind of *hepar carbonis*, and thus facilitating vegetation. The practice of burying dead bodies fo few feet below the furface is a proof of this; as the putrid exhalations from the carcafe are retained, and do not penetrate to the furface. On the fame account, the air over new ploughed fields has long been efteemed falutary to invalids, or convalefcents, as it probably purifies the fupernatant atmofphere. But it was not till lately known that carbon, or charcoal, abforbs with fuch avidity all putrid exhalations; if it has been recently burnt, and has not been already faturated with them: infomuch that putrid flefh is faid to be much fweetened by being covered a few inches with the powder of charcoal, or even for being buried for a time in black garden mould; as putrid exhalations confift chiefly of ammonia, hydrogen, and carbonic acid, and are the immediate products of the diffolution of animal or vegetable bodies; they are believed to contribute much to vegetation, as whatever materials have conftituted an organic body may again, after a certain degree of diffolution, form a part of another organic body. The hydrogen and azote produce ammonia, which combining with carbon, may form an *hepar carbonis*, and by thus rendering carbon foluble in water, may much contribute to the growth of vegetables. It has been faid, that fome moraffes have prevented the animal bodies which have been buried in them from putrefaction; which may in part have been owing to the great attraction of the carbon of the morafs to putrid effluvia, and in part, perhaps, to the vitriolic acid which fome moraffes are faid to contain in their conftitution."

"Then here occurs," fays the author, "an important queftion. By what other means is the folid carbon rendered fluid, fo as to be capable of entering the fine mouths of vegetable abforbents? The carbon, which exifts in the atmofphere, and in lime-ftone, is united with oxygen, and thence becomes foluble or diffufible in water; and may thus be abforbed by the living action of vegetable veffels; or may be again combined by chemical attraction with the lime, which has been deprived of it by calcination. When mild calcareous earth, as lime-ftone, chalk, and marble, has been deprived of its water, and of its carbonic acid by calcination, it becomes lime. Afterwards, when it is cold, if water be fprinkled over it, a confiderable degree of heat is inftantly perceived, which is preffed out by the combination of a part of the water with the lime; as all bodies when they change from a fluid ftate to a folid one, give out the heat which before kept them fluid. At the fame time, another part of the water which was added, is raifed into fteam by the great heat given out, as above mentioned, and the expanfion of this fteam breaks this lime into fine powder, which otherwife retains the form of the lumps of lime-ftone before calcination. But if too great a quantity of cold water be fuddenly added, no fteam is raifed, and the lump of lime-ftone retains its form, whence it happens, that fome kinds of lime fall into finer powder, and are faid to make better mortar, if flaked with boiling water, than with cold. On this account, the lime which is defigned to be fpread on land fhould previoufly be either laid in a heap, and either fuffered to become moift by the water of the atmofphere, or flaked by a proper quantity of water: otherwife, if it be fpread on wet ground, or when fo fpread is expofed to much rain, the heat generated will be diffipated without breaking the lumps of lime into powder, which will then gradually harden again into lime-ftone, difappoint the expectations of the agricultor, and afflict him with the lofs of much labour and expence. When the powder of flaked lime, mixed with fand and water, is fpread on a wall, that part of the water which is not

neceſſary for its imperfect cryſtallization, evaporates into the air, and the lime then gradually attracts the carbonic acid, which is diffuſed in the atmoſphere: but as he ſuppoſes this carbonic acid is diſſolved in the water, which is alſo diffuſed in the atmoſphere, the lime is perpetually moiſtened by this new acquiſition of water from the air, as that which before adhered to it, and had parted with its carbonic acid, evaporates. On which account, new built walls are months, and even years in drying, as they continue to attract water along with the carbonic acid from the air, which ſtands upon them in drops till the lime regains its original quantity of carbonic acid, and again hardens into ſtone, or forms a ſpar by its more perfect, or leſs diſturbed manner of cryſtallization. It is conſequently ſuppoſed, that the earth acquires carbon, both in a manner ſimilar to the above, by its attracting either the carbonic acid, or the water in which it is diffuſed, from the atmoſphere, and alſo by the ſpecific gravity of carbonic acid gas being ten times greater than that of common air: whence, there muſt be conſtantly a great ſediment of it on the ſurface of the earth, which in its ſtate of ſolution in oxygen and water may be readily drank up by the roots of vegetables. Another means by which vegetables acquire carbon in great quantity, may be from lime-ſtone diſſolved in water, which though a ſlow proceſs, occurs in innumerable ſprings of water, which paſs through the calcareous or marly ſtrata of the earth; as thoſe of Matlock or Briſtol in paſſing through lime-ſtone, and thoſe about Derby in paſſing through marl; and is brought to the roots of vegetables by the ſhowers which fall on ſoils where marl, chalk, lime-ſtone, marble, alabaſter, and fluor, exiſt, which include almoſt the whole of this iſland.

By this ſolution of mild calcareous earth in water, not only the carbon in the form of carbonic acid, not yet made into gas, but the lime alſo with which it is united, becomes abſorbed into the vegetable ſyſtem, and thus contributes to the nutriment of plants, both as ſo much calcareous earth, and as ſo much carbon.

And another mode may be by the union of this ſimple ſubſtance, with which all garden mould abounds, with pure calcareous earth into a kind of hepar, analogous to the hepar of ſulphur made with lime, which abounds in ſome mineral waters, and this is ſuppoſed to be the great uſe of lime in agriculture."

For the purpoſe of aſcertaining the probability of this mode of ſolution of carbon, the following experiment was made. "About two ounces of lime in powder was mixed with about as much charcoal in powder, put into a crucible, and covered with about an inch or two of ſiliceous ſand. The crucible was kept red hot for an hour, or longer, and then ſuffered to cool. On the next day water was poured on the lime and charcoal, which then ſtood a day or two in an open cup, and acquired a calcareous ſcum on its ſurface. And though it had not much taſte, except that of the cauſticity of the lime, yet on dropping one drop of marine acid into a tea ſpoonful of the clear ſolution, a ſtrong ſmell like that of *hepar ſulphuris* was procured, or like that of Harrowgate water, which evinced that the carbon was thus rendered ſoluble in water. Hence, the doctor ſuggeſts, that the ſulphureous ſmell of Harrowgate and Kiddleſton waters, and other ſimilar ſprings, may be owing to the union of the alkali of decompoſing marine ſalt, with the carbon of the earth they run through, and that this kind of water might thus poſſibly be uſed as a profitable manure in agriculture."

And a ſtill further method by which vegetable roots acquire it, is ſuſpected to be "by their diſuniting carbonic acid from lime-ſtone in its fluid, not its gaſeous ſtate, which the lime-ſtone again attracts from the atmoſphere, and conſolidates, and forms other matters included in the ſoil. Firſt, becauſe lime is believed by ſome agriculturs, who much employ it, to do more ſervice in the ſecond year than the firſt, that is, in its mild ſtate, when it abounds with carbonic acid, than in its cauſtic ſtate, when it is deprived of it. Secondly, that the uſe of burning lime ſeems hence to be ſimply to reduce it to an impalpable powder, almoſt approaching to fluidity, which muſt facilitate the application of the innumerable extremities of vegetable fibres to this incalculable increaſe of its ſurface; which may thence acquire by their abſorbent power, the carbonic acid from theſe minute particles of lime, as faſt as they can recover it by chemical attraction from the air or water, or other inanimate ſubſtances in their vicinity. Thirdly, the hyperoxygenation of the perſpirable matter of the plants, which thence gives up oxygen gas in the ſunſhine, would induce us to believe that a great part of the carbon which furniſhes ſo principal a part of vegetable nutriment, was received by their roots in the form of carbonic acid; and that it becomes in part decompoſed in their circulation, giving up its oxygen; which thus abounds in the ſecreted fluids of vegetables from this ſource, as well as from decompoſed water, as is generally known. And laſtly, there is another way by which carbon is received into the vegetable ſyſtem, which is by its exiſtence in ſugar and in mucilage, both of which are taken up undecompounded, as appears by their preſence in the vernal ſap-juice, which is obtained from the maple and the birch, which like the chyle of animals, is abſorbed in its undecompounded ſtate by the roots of plants." This matter muſt of courſe be conſidered as one of the principal conſtituent parts of vegetables; and would ſeem to enter into, and accumulate in the conſtitutions of plants in proportion to their ſucceſſive growth. Some plants, however, take more into their compoſition than others, as from the reſult of chemical analyſis, a quantity almoſt equal to all their other component parts has been found in particular inſtances, as in *agaricus piperatus*, *clavaria aurea*, *agaricus*, *lycoperdon teſſellatum*; while in others, only a very ſmall portion."

Carbonic Acid

CARBONIC ACID, CARBONIC ACID GAS, or *Fixed Acid*.—Aerial acid.—Mephitic acid.—Kohlenfaure, Germ. —Acide carbonique, Fr. in *Chemiftry*.

Carbonic acid, in its uncombined ftate, is only known to us as a gas, and it is the firft gas in which acid properties were clearly difcovered. It is known to be fo by reddening certain vegetable blues, by neutralizing alkalies and alkaline earths, and by being formed by the union of a combuftible bafe.

The fources of this acid are immenfe, and widely diffufed. The chief are the following.

1. The atmofphere always contains a fmall portion, which varies in the immediate vicinity of places where the proceffes of refpiration and combuftion are going on, though fomewhat lefs than might be expected. The general average is eftimated at about one hundredth part. It is readily extracted from a confined portion of the atmofphere by the contact of lime or the cauftic alkalies.

2. Almoft every natural fpring, as it rifes from the earth, contains a portion of this air; and fome waters hold fo large a portion as to give them, when expofed to the air, a very brifk, frothy appearance, and a very fenfible tafte and decidedly acid properties The celebrated fprings of Spa, Pyrmont, and Seltzer, are of this kind, and the moft highly carbonated water of them contains about its own bulk of the gas.

3. Every procefs in which coal, wood, or any other carbonaceous fubftance is burnt, is one which generates this acid gas. The fame may be faid of the procefs of refpiration.

4. The vegetation of plants under fome circumftances generates carbonic acid.

5. The fpontaneous decompofition of vegetable and animal matter produces this gas in abundance; hence fermentation and putrefaction are carbonating proceffes.

6. But the largeft ftore of carbonic acid that exifts is that enormous quantity which is folidified in all the immenfe beds of lime-ftone, chalk, and calcareous ftones with which every part of the globe abounds. Many of thefe contain 40 per cent. or even more of their *weight* of this acid.

Carbonic acid gas, or fixed air, has the following properties. It is permanently gafeous at any temperature or preffure. It is fatal to animal life, any living creature immerfed in it perifhing as foon as it would by total interruption of refpiration. Hence the fmall, warm-blooded animals die in it almoft immediately; dogs, and animals of bulk, fpeedily become fenfelefs in it, but recover, if removed in a fhort time; frogs, and cold-blooded animals, live in it for a confiderable time, owing to their power of fubfifting for a time without external refpiration; but when this is paft they perifh as the warm-blooded animals. This air is equally incapable of maintaining combuftion, fo that a candle let down into a jar of it is extinguifhed as foon as it enters the gas as effectually as if dipped into water. Even the admixture of fo fmall a proportion as one-ninth of carbonic acid gas renders common air unable to maintain combuftion, according to Mr. Cavendifh's experiments. It is the heavieft of all the known gaffes, except the fulphureous. Hence, as foon as generated, it falls through the atmofphere to the loweft places, unlefs mingled with it by agitation or long ftanding. Thus, if a jar of fixed air is inverted from fome little height over a burning taper, enough of it falls unmixed upon the taper to extinguifh it. The weight of this gas is,

in all circumſtances of preſſure and temperature, to that of common air very nearly as three to two; hence its ſpecific gravity will be about .001806, and the weight of a cubic inch at 60° therm. and 29.5 inch bar. will be about .456 of a grain.

This gas alſo combines readily with water and many other ſubſtances, as will be preſently mentioned. Its combinations with the alkalies, earths, and metals, are called *carbonats*.

Carbonic acid gas is procured, for experiment, generally from lime-ſtone, chalk, marble, or any carbonat of lime, either by heat or by the action of an acid, almoſt any of which will diſlodge the carbonic from its baſes, and cauſe it to aſſume a gaſeous form. The mild alkalies may alſo be uſed for this purpoſe. The action of acids always produces an effervescence, or frothing at the ſurfaces of contact, owing to the rapidity with which the carbonic acid takes the form of a gas; and hence all ſtones that effervesce with acids may be preſumed (with but few exceptions), to conſiſt chiefly of carbonat of lime. To obtain carbonic acid gas in quantity and in a regular, uniform ſtream, put a number of ſmall lumps of marble or calcareous ſpar in any proper veſſel, pour on them ſulphuric or rather muriatic acid diluted, and receive the gas as it is generated. If it is collected over water, ſome will be loſt at firſt, owing to the abſorption of a portion by the water itſelf. Or elſe, put ſome dry chalk or marble, or eſpecially carbonat of magneſia, in an earthen retort and heat it to redneſs. The carbonic acid gas then comes off in abundance. When decompoſed by acids, a grain of marble will yield nearly a cubic inch of gas.

As all mixtures under the vinous fermentation, give out an abundance of this gas, this affords a ready way for procuring it, and ſubſtances under experiment may be immerſed in an atmoſphere of the gas by being ſimply ſuſpended over the fermenting vats of brewhouſes.

Carbonic acid gas is readily abſorbed by water; and thus the natural carbonated waters may be eaſily imitated. This fluid has a pungent, agreeable, briſk taſte, and bubbles vigorouſly, when expoſed to air, the more in proportion to the temperature. This abſorption is ſhewn in a very eaſy manner, ſimply by filling a phial with water, then diſplacing about half its contents, by throwing up the gas, and then preſſing the finger cloſe againſt the mouth, ſhaking the half-full bottle violently. It will then abſorb ſo much of the gas as to make nearly a vacuum within, which will be felt by a ſtrong external preſſure of the atmoſphere on the finger that ſhuts the communication. This abſorption is alſo equally promoted by ſubjecting the gas to ſtrong preſſure, when in contact with the water that is to abſorb it; and it is by the united action of preſſure and agitation that the manufacture of the carbonated medicinal waters (ſuch as the artificial Seltzer, and the like), is carried to ſuch great perfection.

Water, at about 50° temperature, will abſorb, by mere agitation, nearly its own bulk of carbonic acid gas; but by the combined action of preſſure and agitation, three times as much may be thrown in.

Mr. William Henry, in his valuable experiments on the abſorption of gaſſes by water, (Phil. Tranſ. for 1803,) has ſhewn that the quantity of gas abſorbed is (*ceteris paribus*), regulated by the purity of the gas; for, even if the gas itſelf is obtained unmixed with any other, ſome addition of atmoſpherical air muſt take place from the veſſels in which the experiment is made, and alſo from the water, which cannot be abſolutely purged of common air by boiling or any other method. Hence Mr. Henry found, that if 20 meaſures of nearly pure carbonic acid gas were agitated with 10 meaſures of water, full 10 meaſures of the gas would be abſorbed; but if 20 of the gas, mixed with 10 of common air, were agitated with the ſame quantity of water, only ſix meaſures could be taken up. Water alſo parts with a great proportion of its carbonic acid by mere expoſure to air, which is independent of the circumſtance of removing the mechanical preſſure of corks, &c.; for Dr. Brownrigg found that the gas would not eſcape from Seltzer water, when in a cloſe bottle, though a looſe empty bladder ſupplied the place of a cork, and in which, therefore, the gas had ample room to expand itſelf; but a free communication with the air was neceſſary for this eſcape. The abſorption of the gas is inverſely as the temperature of the water; cold water abſorbing much more than warm. The diminution of abſorption, on raiſing the heat, Mr. Henry eſtimates at about $\frac{1}{11}$th of the whole for every ten degrees above 55°. With regard to the effect of preſſure, it appears that water, in all caſes, takes up as great a bulk of condenſed as of expanded gas, under ſimilar circumſtances of temperature.

Therefore, as the bulk of all aeriform bodies is inverſely as the preſſure to which they are expoſed, the quantity abſorbed is directly as the preſſure; that is, for example, if a preſſure of 30 inches of mercury will cauſe a certain bulk of carbonic acid to be abſorbed, a preſſure of 60 inches will cauſe a double abſorption.

The ſpecific gravity of water, holding its own bulk of carbonic acid, is about 1.0015. This gas is readily and almoſt totally again expelled by heat; hence, in the analyſis of mineral waters, the firſt ſtep to be in general purſued is the expulſion of the gaſſes which it may contain, by boiling for about ten or fifteen minutes.

Carbonated water ſhews its acid properties by changing the colour of litmus from blue to red. This it will do, according to Bergman, when the water contains as much as $\frac{1}{18}$th of its bulk of the gas. It is very conveniently ſhewn, in the way mentioned by Kirwan, that is, by adding, in a thin glaſs tube, or jar, about equal quantities of the carbonated water, and of litmus infuſion diluted, ſo that the blue is juſt diſtinguiſhable. The colour then becomes of a very dilute red, and is better remarked when compared with a ſimilar glaſs tube full of the ſame dilute litmus liquor and plain water. To ſhew that it is the carbonic and no other acid that produces this change, let ſome of the carbonated water be boiled ſtrongly for a few minutes, and then it will leave the blue unaltered.

But lime-water is a much more delicate teſt for carbonic acid, either gaſeous or liquid. When a gas is to be tried, nothing more is required than to ſhake it with lime-water, or with barytic or ſtrontian water, and the immediate mildneſs of the water will indicate the preſence of carbonic acid gas in almoſt every caſe.

But with liquid carbonated water, it ſhould be remembered, that though the firſt portion of carbonic acid will precipitate the lime from its ſolution in the form of white carbonat of lime or chalk, a greater portion of the acid will re-diſſolve the *carbonat of lime*. So that if a highly carbonated water and lime-water be mixed together at repeated portions, the mixture will firſt become turbid by the ſeparation of the carbonat of lime; then an additional quantity of carbonated water will make it again clear by re-diſſolving the carbonat; after which another portion of lime-water will again make it turbid, and freſh carbonated water again clear, and ſo on, in proportion to the mutual ſaturation and ſuperſaturation of the two ingredients. Therefore, as no error can ariſe from an exceſs of lime-water, the latter, to ſhew, in all caſes, the preſence of carbonic acid, ſhould be in equal quantity with the carbonated water. According to Bergman's valuable reſearches on carbonic (called by him *aerial*)

acid, lime-water will detect by its cloudiness as little as one cubic inch of the gas in 7000 grains of water, that is, where the weight of the gas is only $\frac{1}{14000}$th of the whole.

This gas is also readily and totally absorbed from any gaseous mixture by slight agitation with a solution of caustic or nearly caustic alkali. A much smaller quantity of alkaline solution will suffice than of lime-water, as the former may be made much more concentrated. This is often convenient; but it is not so palpable a test, as no cloudiness or change of appearance in the alkaline solution ensues.

Carbonic acid, according to the modern system of nomenclature, signifies an acid whose basis is carbon; and hence that it is produced by the combustion or oxygenation of carbon or pure charcoal. It required the united efforts of many of the most eminent chemists to elucidate the nature of this important acid, and to shew that the very same substance which existed as a large component part of all calcareous stones, and was given off abundantly by many of the natural mineral waters, was also the sole product of the combustion of charcoal, and all carbonaceous matters. The full discovery and proof of this fact are due to Lavoisier, who made the elementary experiment of burning a given weight of charcoal in oxygen gas of known purity, (no other substance being introduced than a very minute portion of phosphorus to begin the combustion,) and found the product of the combustion to be this acid gas, the weight of which, when removed by caustic alkali, corresponded very exactly with the loss of charcoal and oxygen. Very little actual diminution of bulk takes place at first in this combustion, since the product is itself a gas, and not a liquid, as happens after the combustion of sulphur, phosphorus, &c. and therefore it is not till caustic alkali or lime-water is introduced that the production of the carbonic acid, and consequent loss of oxygen, are made apparent. From this elementary experiment, Lavoisier infers, that carbonic acid is composed of about 28, by weight, of charcoal, and 72 of oxygen, and the results of subsequent inquiries nearly, if not absolutely, confirm the accuracy of this statement.

Carbonic acid is at its highest state of oxygenation, and is the only state in which it has acid properties. United with less oxygen it forms the *carbonous oxyd* as noticed in the last article, in which, also, the partial disoxygenation of carbonic acid and consequent production of the carbonous oxyd are described.

Carbonic acid has been *completely* disoxygenated (that is, reduced to black pulverulent charcoal) by only one substance, namely, by phosphorus. This discovery was made by Mr. Tennant, and was followed by other valuable experiments by Dr. Pearson. (Phil. Trans. for 1791-2.)

From the well known fact that phosphorus cannot be made by distilling phosphat of lime and charcoal, the latter not having the power of decompoſing this acid when united with lime, Mr. T. inferred that the united actions of phosphorus and lime might be sufficient to decompose carbonic acid by a stronger affinity with its oxygen. He accordingly put some phosphorus into a coated glass tube closed at one end, and over the phosphorus some powdered marble. The open end of the tube was then also closed, except a very small aperture, to prevent the free access of the external air, and the tube was then heated red hot for a few minutes. When cold and broken it was found to contain a black powder consisting of true charcoal mixed with both phosphat and phosphuret of lime, together with some undecomposed marble. In this experiment the only source of the black carbonaceous powder can be the carbonic acid of the marble, which appears to have been decomposed by complicated affinities, namely by that of part of the phosphorus for the oxygen of the carbonic acid, of the rest of the phosphorus for the lime forming the phosphuret of lime, and also by the phosphoric acid (as soon as formed) for another portion of the lime forming the phosphat of lime. Or, in other words, the carbonat of lime must undergo two disuniting processes before the charcoal can be produced, namely, the carbonic acid must be separated from the lime to which it has a certain affinity, and also the oxygen of the carbonic acid must be separated from the carbon which is its base. The lime is detached from its union with the carbonic acid by the united affinities of part of the phosphorus for lime, and also of the phosphoric acid, when formed, for the lime. On the other hand, the carbonic acid is decomposed by the direct affinity of phosphorus for oxygen, which is great, but however of itself less than that of carbon for oxygen, since, in the common distillation of phosphorus, it is produced by decomposing phosphoric acid with charcoal. Therefore the decomposition of carbonic acid here produced is the result of combined affinities, and could only be effected in this manner.

Dr. Pearson decomposed carbonic acid by a similar process, but with phosphorus and carbonat of soda instead of carbonat of lime. Sufficient quantity of the black powder was procured in both cases to prove that it was genuine charcoal, and yielded carbonic acid again on combustion with nitre.

Many liquids absorb carbonic acid with apparently as much ease as water, such as alcohol, oil, &c. but such mixtures seem to produce no remarkable chemical change.

The affinity of carbonic acid with the alkalies, earths, and metals, is so weak that it may be displaced by every other acid, the boracic excepted. This weakness of affinity is doubtless much owing to the tendency which it has to assume a gaseous form as soon as disengaged.

The order of the affinities of this acid in the liquid way for the alkalies and earths is barytes, strontian, lime, potash, soda, magnesia, and ammonia. With regard to the two latter indeed, the force of affinity is so nearly balanced that each substance will partially decompose the carbonat of the other according to the temperature. Thus at a higher heat the ammonia, from its increased tendency to volatilization, loses much of its force of affinity with solid or liquid bases, and then its carbonat is decomposed by magnesia, which no heat can volatilize; but in a low temperature the affinity of the ammonia prevails and it decomposes the magnesian carbonat, though very imperfectly.

As the carbonic acid quits every substance in a high heat its relative affinities in the dry way cannot be ascertained.

Carpentry

CARPENTRY, in *Civil Architecture*. The art of carpentry is, in general terms, the art of employing timber in the construction of edifices. This is an art of the most general and important use, and of the highest antiquity; from the rude and solitary cabin to the rich and peopled city, in the earliest dawnings and the brightest periods of civilization, wherever nature has presented to man her forests, the building art has found in them a material of universal application, commodious and economical. Carpentry is also interesting to the fine arts, as its forms and operations have been the model of Grecian architecture, which has decorated and improved, but never renounced, its original type in wooden building. See the articles BUILDING and CIVIL *Architecture*.

With respect to the history of this art our information is short and scanty. Pliny and Vitruvius, the only writers upon the building arts whose works have reached modern times, confine their observations upon carpentry chiefly to the choice and felling of timber; and it may be readily conceived that ancient buildings preserve no specimens of an art which is not calculated to resist the injuries of time and the violences of rapine.

The remains of Egyptian architecture present, perhaps, the only example of a complete system of building without the use of timber, while, at the same time, arches and vaults were unknown; for many Roman edifices, such as the Pantheon, Temple of Peace, &c. might be quoted, which, by means of vaults, are independent of carpentry. In the Egyptian construction, however, flat roofs of massy stone were used, which it was necessary to support by thick-set avenues of columns, arranged at small equal distances over the whole area. This form, though sufficiently striking and picturesque, was of course incommodious, and only adapted to a dry climate. A pediment roof, therefore, was the first effort of constructive carpentry; this answered the purpose of an effectual shelter, by throwing off the humidity of the skies; at the same time, the rafters, in connexion with the transverse beams of the ceiling, formed a truss which would be gradually improved, and thus give the means of covering a wide space, without any other support than the external walls.

The invention of pediment roofs leads us naturally to Greece, where this member was an essential part of architecture. Besides forming roofs, the Greeks appear to have used carpentry in the framing of floors, and for rustic buildings and other purposes. But in a warm climate, abounding with stone and marble, it is not probable, that wood was much used in the internal finishing of any edifices, except for those objects wherein lightness and tenacity are essential qualities, as doors; though there are some remains of marble doors. Museum Worsleyanum.

This was less the case in Rome. The Romans seem to have used wood for nearly all the purposes of carpentry that the moderns are acquainted with. The roofs of buildings, the architraves, where they were very long, as in the Tuscan temples and other cases, the framing of floors, were all of this material. They also formed arches of slight timber grating

for ſtuccoing; they had wooden cornices, and the ſtone ſeats of theatres were covered with boarding. Vitruvius, l. 4. l. 7. &c. We alſo read of conſiderable buildings, as amphitheatres, being erected of wood; ſuch was that built by Auguſtus to exhibit the ſhows on account of the victory of Actium, and many others, at Rome and different parts of Italy. It may be remarked that the beams of the roof were generally left uncovered by a ceiling; and ſometimes, in magnificent buildings, encruſted with bronze, and even gilded as in the baſilica of St. Peter, erected by Conſtantine.

In the colder countries of Europe, wood was more plentifully uſed, particularly in the interior works; and in the middle ages the art of carpentry partook of the bold and ſkilful conſtruction exhibited in that ſtyle of building commonly called gothic; of this the high pitched weighty roofs and lofty ſpires of the great cathedrals afford many ſtriking inſtances.

In more modern times carpentry ſtill improved. The wooden bridges of Palladio are examples of admirable conſtruction. Some French artiſts too have given eminent inſtances of ingenious carpentry, as Philibert Delorme in his method of conſtructing wooden domes; and Moulineau in his, which was executed at the Halle du Bled, at Paris, and various centres for large ſtone arches by Perronet, Hupeau, &c. In England the timber work of the dome and ſcaffolding of St. Paul's, and, in later times, many examples of centres, bridges and roofs may be cited as models of ſcientific carpentry: while in accuracy of execution, celerity and neatneſs of finiſhing, our workmen are unequalled. In the north of Europe, and particularly in Sweden and Norway, wood is almoſt the only material uſed for building; and of courſe the natives muſt have conſiderable practical ſkill in carpentry.

The art of employing timber in building is divided into two grand branches: carpentry and joinery. The firſt includes the larger and rougher kinds of work, and that part which is material to the conſtruction and ſtability of an edifice; and, generally, all the work wherein the timber is valued by the cubical foot. Joinery, which is called by the French, menuiſerie, from the menus bois, or ſmall wood employed in that art, includes all the interior finiſhing and ornamental wood-work, and is valued by the ſuperficial foot.

In this article we ſhall treat of the conſtructive part, or carpentry, ſtrictly ſpeaking, leaving what reſpects the material and belongs to architecture in general, as the choice of trees, the ſtrength of timber, &c. to the article TIMBER. We ſhall therefore ſuppoſe the material arrived in the carpenter's yard, and in the ſtate of whole or ſquared timber. The operations it undergoes from this period to its final employment in a building may be claſſed under two general heads, thoſe which relate to individual pieces, and thoſe which relate to their connexion with others. Under the firſt head are the operations of the pit ſaw, too generally known to need deſcription, by which the whole timber is divided and reduced to the required *ſcantlings;* this term, from the French, *echantillon*, means dimenſions, relative to breadth and thickneſs without reſpecting length:—Planing, which is giving a ſmooth face to wood by means of a familiar inſtrument called a plane, conſiſting of a chiſel fixed in a frame, ſerving as a handle, by which the workman moves it along over the ſurface of the timber, ſhaving off its inequalities: timber thus prepared is ſaid to be wrought:—Mouldings of various forms, and performed with particular planes or chiſels:—Rebating, which conſiſts in diminiſhing the width of a ſquare, or rectangular piece of timber, for a certain depth on one edge, thus taking off a rectangle of the whole width, and leſs than the depth of the original piece; this method is particularly uſed in door-caſes, and the frames of caſement windows, the *rebate* forming a kind of ledge for the door or caſement to ſtop againſt:—Grooving or plowing, in which a narrow channel is excavated out of the thickneſs of the timber: the groove is either ſquare, forming an equal ſection in the whole depth, or wider at bottom than at top, which is called a *dovetail* groove. Timber may alſo be *ſunk* where the piece is formed like a wedge, or rounded; or *bevilled* in various ſhapes, which means when the ſection forms a figure without right angles.

We now come to the ſecond and moſt important head of the operations by which timbers are connected together. Theſe are generally ſpeaking, by *mortiſe* and *tenon*, the firſt an excavation, and the ſecond a projection, adapted to it; or by wooden pins or nails, ſpikes, ſcrews, bolts, ſtraps, and other faſtenings of metal, or by glue, though this laſt is ſcarcely uſed except in joinery.

The following is a deſcription of the moſt general and uſeful methods of joining timbers. Firſt, by ſimple tenon and mortiſe, as when joiſts are framed into trimmers, the moſt uſual method is to make the tenons in the middle of the breadth of the trimmer with a plain ſhoulder; ſee *fig.* 1. *Plate* LXII. of *Architecture*, which repreſents a ſection of the trimmer, and a part of the joiſt, framed in a longitudinal direction. But when binding-joiſts are framed into girders, as the binding-joiſt has to ſupport the bridging-joiſts, and theſe the floor, the beſt method, in order to give ſtrength to the tenon, is to make a reſt of a ſhort length under the tenon, with a ſloping ſhoulder above, extending in a line from the extremity of the reſt to the perpendicular of the ſquare ſhoulder below at the upper edge of the binding joiſt. See *fig.* 2. *Plate* LXII. of *Architecture.* No. 1. repreſents a ſection of the girder through the mortiſes; Nos. 2 and 3 part of the joiſts in a longitudinal direction.

When a piece of timber is to be framed between two parallel pieces which are quite immoveable, the true method, in order to make cloſe work, is to make the extremity of the tenon and the bottom of the mortiſe, at one end, in the arch of a circle, having its centre in one edge of the mortiſe, and the extremity of the tenon, and the bottom of the mortiſe at the other end, in a concentric arch from the ſame centre. As the mortiſe at this end muſt be much longer than the breadth of the tenon, there will be a large part of the mortiſe ſtill open, which may afterwards be filled up. Inſtead of the bottom of the mortiſe here being formed in the arch of a circle, it may be cut quite parallel to the edge to the deepeſt part, as it will not impede the tranſverſe piece in going to its place. This mode of framing is much uſed in ceiling, joiſting for double floors: the long mortiſes cut in this manner are called chaſe mortiſes. In forming the tenon and mortiſe, at the end where the centre is placed, it is not neceſſary that the mortiſe and tenon ſhould be ſo deep as to form an entire quadrant; in this caſe the bottom may be quite parallel, and only the further edge oppoſite the centre made circular. *Fig.* 3. *Plate* LXII. of *Architecture* repreſents a piece of framing, in the manner above deſcribed, A B, the bottom of the mortiſe, and the extremity of the tenon deſcribed from the centre C; D E the running, or chaſed mortiſe, which muſt be quite free from the circumference deſcribed by the point D, whether the extremity be in the circumference, or in a tangent, D F, parallel to G E.

The manner of repreſenting the tenon and mortiſe at the end on which the centre is placed, when the mortiſe is made of a leſs depth than the breadth of the tenon, is ſhewn at the other end.

When a tranſverſe piece is to be framed between two pa-

rallel joists, of which their vertical surfaces are oblique to each other, the upper edge of the transverse piece is turned downwards upon the top of the joists, and marked at the interval or clear; it is then turned upwards into the position in which it is to be placed, the mark at one end is brought into a right line with the vertical surface of the joist, and a line is drawn by the edge of a rule or straight edge placed vertically in the plane of the joist and the transverse piece; this line marks the shoulder of the tenon. The other end is drawn in the same manner. This mode of framing a transverse joist between two parallel joists is called by workmen tumbling-in-joists. The manner of tumbling in a joist is exhibited at *fig.* 4. *Plate* LXII. of *Architecture*. A and B are sections of the parallel joists, C D E F the transverse joist, or the piece tumbled in, G H the straight edge placed for drawing the shoulder C F.

A piece of timber may be joined at right angles to another in the manner of *fig.* 3. *Plate* LXI. of *Architecture*, which is a longitudinal section in the direction of the fibres of both pieces. A mortise is cut in the one piece to the breadth of the piece which is to form the perpendicular: the edge of the tenon is cut with a dove-tail notch, so that the piece may be at right angles to the other, and a wedge or key is driven from the other edge of the tenon, which forces it quite close. One inconvenience arising from the dove-tail is, that if the timber of which it is made be not quite dry, the tenon will shrink in proportion to its breadth, and therefore the perpendicular piece will be liable to be drawn to a certain degree. To remedy this defect, instead of the edge of the tenon being cut dove-tail ways, it may be notched, as is to be seen in *fig.* 4. No. 1. No. 2. shews another view of the perpendicular piece with the wedge.

Another method of fixing one piece of timber perpendicular to another, is to mortise the piece forming the base not quite through, enlarging the edges towards the bottom, and making the tenon of the perpendicular piece to fit the upper part of the mortise. Two wedges are then fixed to the bottom of the tenon; where the perpendicular piece is driven, the wedges will be resisted by the bottom, which will split the ends of the tenon, and fill up the mortise to the breadth at the widest place. This mode of fixing one piece at right angles to another is called fox-tail wedging. By this method, so long as the wedges are kept from slipping, the one piece can never be drawn from the other, without breaking the tenon. In order to enlarge the tenon in breadth still more towards its extremity, two other smaller wedges may be put in, of which their ends do not reach quite so far as those of the other two, which, when partly driven, the small wedges will then begin to widen the end of the tenon likewise, and make it fill the mortise completely at the bottom. *Fig.* 5. No. 1. shews the edge of the piece on which the mortise is cut. Fox-tail wedging is chiefly used where the pieces to be put together are small, and then the wedges are frequently driven in with glue; when the pieces to be joined are large, the former method is generally practised.

The fixing beams to wall-plates is called cocking or cogging. When a beam is to connect two wall-plates, in order to bind the sides of the building together, one method is to cut the end of the beam in the form of a dove-tail, and to make a correspondi ng notch in the wall-plate to receive it, as is shewn in *fig.* 6. No. 1. No. 2. is a transverse section at the neck of the dove-tail. *Fig.* 7. shews the same thing, with a small variation in the form of the dove-tail, fitted obliquely to the other piece. But when the timber has not been sufficiently seasoned, and when it begins to dry, the perpendicular piece may easily be drawn from the other, to a certain degree. Therefore, if the sides of the building are affected by lateral pressure, this mode of fixing the one piece to the other will not prevent the walls from coming nearer together, or expanding. The most effectual method of preventing this is shewn at *fig.* 8. No. 1. where a small notch is cut out of the beam, and the contrary parts, viz. a double notch, cut in the wall-plate to receive it. No. 1. the beam shewn longitudinally upon a transverse section of the wall-plate; No. 2. the upper face of the wall-plate. The best method of connecting any number of posts with cross-beams depends upon this principle. *Fig.* 9. No. 1. shews a transverse section of a post with two beams longitudinally bolted to it, in the manner of cogging beams to wall-plates: No. 2. a part of one of the beams, shewing the notches. The strongest method of fixing the purlins of a roof to the rafters also depends upon the same principle. *Fig.* 10. No. 1. is a section of the rafter, with the purlin longitudinally drawn; No. 2. the upper edge of the rafter; No. 3. the under side of the purlin, shewing the notch.

The method of joining timber laterally, by means of keys and dove-tails, is ingenious, and not generally known; it will be necessary to exhibit and describe the manner of doing it. *Fig.* 1. *Plate* LXI. of *Architecture*, No. 1. is a longitudinal section of two pieces joined in this manner, with the dove-tail pieces and the wedge or key, by means of which they are forced against the ends of the pieces to be fixed, and in order to make the one press harder to the other, the interior angle of the dove-tails is greater than the exterior one, formed upon the pieces to be joined; No. 2. is a transverse view of the mortise, exhibiting the ends of the dove-tails and keys. *Fig.* 2. is the same method, applied in joining parallel pieces not touching each other together, which is plain to inspection.

The modes in which beams are lengthened are of infinite variety; some of the most approved forms are as follow. A beam may be continued to any extension by building it in three thicknesses; see *fig.* 1. *Plate* LX. of *Architecture*. It may also be done by splicing one to the end of another, called by carpenters scarfing, which is of various forms, as in *figures* 1, 2, 3, 4, 5, 6, 7, and 8. When a beam is to be lengthened, as in *fig.* 2. and 3. it is very difficult to get the joints close when the pieces composing it are very large, and hence they are seldom used but for very small pieces, which may be glued together. To remedy this inconvenience in large works, as well as to make it less dependent on the bolts; and to prevent every possibility of the one being drawn away from the other, is to indent them together, called tabling, as in *figures* 4, 5, 6, 7, 8, and 9, and to leave a small space at the end or meeting of each table for a wedge. In the operation of joining timbers in this manner, the pieces are laid so as to bring the joint as close as possible, the wedge is then driven while another person strikes the extremity of one of the pieces with a large hammer or mallet, which will bring the joint quite close, if they have been well fitted together previously to the operation; of these two forms, *figures* 5, 6, and 7 ought to have the preference, as the faces of the tables are parallel to the fibres of the wood, which will make them resist any longitudinal strain with a much greater force; but as a disadvantage arises from this form, that more than half the wood is cut quite through at the two ends of the joints, it has been found necessary to fix plates of iron across them, as are shewn. However, there is less to be apprehended from the tearing of the fibres, by being drawn in a direction of their length, than from the bending of the bolts.

Fig. 6. is a scarfe with several tablings; in this it is to be observed, that the wedges in the two extreme mortises are only effective. A wedge in the middle would tend to force the joints open, and therefore the other two should only be

fixed. Long ſcarfings add to the ſtrength; but to increaſe the number of tables more than two, is, it is thought, rather diſadvantageous, as it ſhortens its fibres, and conſequently makes their reſiſtance leſs. *Fig.* 7. is an excellent method of ſcarfing in two pieces, each piece being tabled together, as in *fig.* 5. It has been thought by ſome that tabling ſcarfings leſſen the ſection of reſiſtance more than is neceſſary; and for this purpoſe they prefer *fig.* 8. with an oblique ſcarf, where the keys are let half into the one and half into the other: but in this mode, as a draught muſt be left for the keys, they will be apt to be turned round in the driving, and therefore will have leſs effect in keeping the pieces together. *Fig.* 9. is a mode of ſcarfing a beam by tabling the pieces together; No. 1. and 2. are the two halves; when bolted together they have the appearance of being quite ſtraight, as is ſhewn in No. 6. The tables are made in the form of obtuſe angles, with a ridge in the middle, depreſſed and raiſed alternately, in the form of re-entering and ſalient angles; No. 3. ſection acroſs the depreſſed part; No. 4. ſection acroſs the raiſed part; No. 5. ſection of the beam when bolted together. In all forms of ſcarfing whatever, every butting joint ſhould be ſtrapped acroſs with iron on both ſides; this will in a great degree prevent the bolts from being bent, and will increaſe the longitudinal reſiſtance at the weakeſt ſection. If a beam is to be ſcarfed and tabled as in this laſt mode, the utmoſt care ought to be taken in the workmanſhip, ſo that all the butting-places ought to be cloſely fitted together.

Connected with ſcarfing is the method of joining timbers, which may either be endways, ſideways, perpendicularly, or obliquely. When two pieces of timber are ſo joined that the common ſeam or joint is perpendicular to the fibres of both pieces, then the joint is ſaid to be butting, and is called by workmen a butting or heading joint. When two pieces of timber are joined together, ſo that the common ſeam is parallel to the fibres of both pieces, this then may be called lateral or longitudinal joining, and the joint may be called a longitudinal joint, as it runs in the direction of the grain; and when the fibres and ſeam of the one piece run perpendicular to the fibres of the other, this mode of joining timbers may then be called tranſverſe joining, and the joint may be called a tranſverſe or perpendicular joint. Laſtly, when the fibres of the one piece run obliquely to thoſe of the other, this is called oblique joining, and the joint is called an oblique joint.

Butting joints for many purpoſes are preferable to ſcarfings, particularly in ſmall work, ſuch as the hand-rails of ſtairs.

They are fixed together with bolts, having a ſcrewed nut at each end, the head of one of theſe nuts muſt be quite round and the other ſquare; the round one muſt be cut in its circumference full of notches. After having let in the bolt perpendicularly to the joint in both pieces, the nuts are ſunk from one ſide acroſs the grain, until the ends of the bolt may be able to paſs the interior ſcrew made on purpoſe to receive the exterior one; the ſquare nut is firſt put in and the one end of the bolt is firmly driven into the bore made on purpoſe to receive it, and ſcrewed to the nut. The other notched nut is then put in, and the bolt in its place; the one piece may be turned round upon the other until the joint is cloſe, but in order to ſecure the joint from turning round, two dowels may be inſerted on each ſide of the bolt. Drive the one piece as cloſe to the other as the nut will permit. Then by means of a narrow pointed ſcrew-driver and mallet, the nut may be turned round until the joint is quite cloſe.

Fig. 5. *Plate* LXII. of *Architecture* repreſents the meeting of a pair of rafters and the king-poſt, together with the manner of ſtrapping them. This mode of forming a junction by making the rafters meet each other, without the intervention of the joggle-head, which is generally made to the king-poſt, has the advantage over the common mode with a joggle-head, exhibited in *fig.* 6. *Plate* LXII. of *Architecture*, as the ſhrinking of the king-poſt at the joggle will allow the roof to deſcend, and conſequently put it out of ſhape.

One method of ſtrapping the tie-beam to the king-poſt is exhibited at *fig.* 7. *Plate* LXII. of *Architecture*. The mortiſe of the ſtrap on both ſides is made oblong, and that through the king-poſt is made ſomewhat lower, in order to give the wedges a proper draught. An idea may be formed by examining No. 1. which repreſents the bottom of the king-poſt with part of the tie-beam; No. 2. is a longitudinal ſection of the king poſt, with a tranſverſe ſection of the beam, in the upper part of this is ſhewn the manner of fixing the wedges, with the form of the waſhers, which are neceſſary in preventing the ſtrap on each ſide from penetrating into the wood, the whole force of the friction being taken away from the ſtraps by them. Another mode of fixing the tie-beam to the king-poſt is by a bolt, as exhibited at *fig.* 8. *Plate* LXII. of *Architecture* No. 1. ſhews the elevation of the bottom of the king poſt; No. 2. is a vertical ſection cutting the beam tranſverſely; in order to give greater ſecurity, there are two nuts, one let in from the face of the beam and the other from the edge. *Fig.* 1. *Plate* LXIII. of *Architecture* ſhews the meeting of a brace and ſtraining-piece under a truſs beam, as the brace may be reſolved into two forces, one puſhing in a direction of the beam, that is, compreſſing the ſtraining-piece, and the other tending to break it tranſverſely, the end of the brace is cut in the form of a ſally, or bird's mouth, as it is called by workmen. Another method is ſhewn at *fig.* 2. *Plate* LXIII. of *Architecture*. This mode is uſed in the roof of Greenwich chapel. See the figures in the article ROOF. It may, however, be obſerved, that this abutment is not of the beſt kind; the ſpace left for the brace to give preſſure to the ſtraining-piece is much too ſmall; the upper part ſhould not be let into the ſtraining or truſs-beam, this prevents the ſtraining piece from acting with its full force, and weakens the truſs-beam.

Fig. 3. *Plate* LXIII. of *Architecture* ſhews the method of ſecuring a collar-beam, at one extremity, to its adjacent rafter, in order to prevent its being pulled away at the joint, a bolt is made to paſs through the rafter at the angle of their meeting.

Beſides what has already been ſhewn of the hanging of king-poſts to their principal rafters, *fig.* 4. *Plate* LXIII. of *Architecture* is another. The rafters meet each other as in *fig.* 5. *Plate* LXII. of *Architecture*, but inſtead of the forked ſtrap, a bolt is here uſed, with a ſpreading head, ſo as to form a ſhoulder at right angles to the rafters, which are notched, in order to receive the bolt. This alſo prevents the rafters of a roof from ſinking in the middle. Inſtead of any part being of wood, the whole may be of iron, conſiſting of two parts, connected together by means of a ſcrew, which will draw the tie-beam higher and higher at pleaſure as it is turned round. No. 1. part of the king-poſt with the bolt; Nos. 2. and 3. part of the rafters; No. 4. view of the upper edge of the rafters. Various forms are ſometimes adopted for the abutments at the bottom of the king-poſt; for the braces, when the king-poſt is not ſufficiently broad at the bottom, as to allow the abutting ſhoulder to be at right angles to the length of the brace, and to its whole breadth. Two of the moſt approved forms are exhibited in *figures* 5. and 6. *Plate* LXIII. of *Architecture*. *Fig.* 5. ſhews the form of the abutment, when the part which makes the reſiſtance

in the direction of the king-poft is at right angles to it. *Fig.* 6. fhews the form of the abutment, when the part of the fhoulders which makes the refiftance is at right angles to the brace; this mode is better than the former, becaufe it is lefs liable to comprefs the king-poft at the bottom.

Fig. 7. *Plate* LXIII. of *Architecture* reprefents one form of the heel of a principal rafter, with the focket cut in the end of the tie-beam to receive it; but as the fmall part cut acrofs the fibres of the beam is fo near to the extremity, and as this part fuftains the whole force of the rafters, in drawing the beam in a direction of its length, it will be liable to be forced away. To prevent this in fome meafure, a double refiftance is formed, as in *fig.* 8. *Plate* LXIII. of *Architecture*, equally deep into the beam; this mode gives the ftrength of the intermediate part contained between the two abutments, in addition to the end refiftance, which is of itfelf equally ftrong with that reprefented in *fig.* 7. The intermediate part in this mode being cut acrofs the fibres, it is eafily fplit away. A more effectual method of forming a double refiftance is fhewn at *fig.* 9. *Plate* LXIII. of *Architecture*, where the heel of the rafter and the focket is cut parallel to the fibres of the beam; the tenon forms the fecond abutment, being removed farther from the extremity. No. 1. the elevation of part of the rafter with part of the beam; No. 2. the upper edge of the beam, fhewing the mortife. But the moft effectual mode of forming a refiftance on the heel of the rafter and focket on the extremity of the beam is that reprefented by *fig.* 10. *Plate* LXIII. of *Architecture*, where the abutment is brought nearer to the inner part of the heel, which leaves a greater length on the end of the beam, in order that the refiftance may ftill be greater than what is given by the wood. A ftrap may be placed round the extremity of the rafter, and the two ends bolted together through the beam, as is fhewn by this diagram at No. 1. and 2.

Fig. 11. *Plate* LXIII. *Architecture* reprefents two braces of a roof meeting an iron king-poft, which is only a fmall rod of iron fufficiently ftrong to hang up the middle of the beam, and to receive the force of the braces by the weight of the middle rafters. The ftrap which prevents the braces from being pufhed downwards, has an eye through each fide, and the bottom of the king-rod is formed with a crofs equal in length to the thicknefs of the braces; this crofs is perforated in its length to receive the bolt.

The purpofes for which wood is employed in modern buildings, and particularly in thofe of England, are very various. It is ufed to form the frame work of the roof, and in laths or boarding, to fupport the covering of tiles, flates, &c. Long pieces, called *bond* or *chain* timber, are laid in the walls to ftrengthen and bind them together: other flat pieces, called *plates* or *wall plates*, are placed to receive the ends of the girders, joifts, and other timbers, which form the framing of the floors, and afford them a level bed. *Ties* are placed acrofs the building to affift in keeping the oppofite walls in their fituation, and counteract the lateral preffure of the roof, and diagonal ties at the angles. *Lintels* are laid over the apertures of doors or windows to fupport the incumbent walls. The floors are framed with various beams and joifts. The rooms are divided with *quarter partitions*, being a frame work of fmall pofts and horizontal and diagonal pieces placed at about a foot afunder, and deftined to be cafed with lath and plafter on the outfide. Door and window-frames are alfo placed in the apertures of the walls. In bad foundations piles are fometimes ufed; and fometimes planking, and what are called *fleepers*, pieces of timber, laid at fhort intervals trafverfely, beneath the foundation wall, and extending about two feet wider: befides all the finifhing wood work, fuch as doors, windows, wainfcoting, &c. which belongs to joinery. Carpentry is alfo employed to conftruct the centres for arching and vaulting, and frequently in entire bridges. Coffer dams, caiffons, flood-gates, and all the methods of building in water, derive large affiftance from this art.

The general principles of meafuring and valuing carpenter's work may be given very fhortly; and to enter into minutiæ would be fuperflous in the prefent work. The timber ufed for building in London, and in the greateft part of England, confifts entirely of oak and fir; the firft the growth of this country, the fecond imported chiefly from Norway. That timber which is out of fight, as being covered with lath and plafter or other facing at the completion of the building, which is by much the greater part, is ufed as it comes from the faw, without the operations of the plane. Of this, part is framed as the roof, floors, partitions. The quantity is meafured by the cubic foot, and either valued as *fir framed*; or elfe the quantity of timber being afcertained, is put down as fir without labour, (*fir no labour*) in the valuation of which is included the original price of the timber, with the expence of cartage, fawing, wafte, and the profit to the carpenter; and a fuperficial dimenfion is taken of the frame or fpace in which the timber was employed under the denomination of *labour* and *nails*, to a floor of fuch a kind, roof, quarter partition, &c. in which is eftimated the value of the workmanfhip, with the mafter's profit. The choice between thefe two methods is influenced by cuftom, and the convenience of the meafurer. The timber ufed in the walls, as the plates, and bond timber, is meafured feparately by the cubic foot, and put down under the denomination of *fir in bond*: this is valued at a medium price between fir framed, and fir without labour. As for the timber which remains apparent after the completion of the building, it is generally worked in fome manner with the plane, and is meafured by the cubic foot, and denominated and valued according to the workmanfhip; thus a doorcafe is *framed*, *wrought*, *rebated*, and *beaded*. We have mentioned only fir becaufe it is infinitely more ufed than oak, however the latter is meafured in the fame way.

Boarding, fuch as weather-boarding, boarding for flates, &c. is meafured by the fuperficial foot, and valued in the bill by the fquare, or 100 fuperficial feet. Timber ufed in very fmall fcantlings, as fillets, is valued, not by the cubic or fuperficial foot, but by the foot in length, called foot run.

Having thus defcribed what is properly included under the general head of carpentry, the reader is referred, for more particular information, to the articles Centre, Floor, and Roof; under which articles that part of conftructive carpentry which depends on certain branches of mechanics and geometry will be fully explained.

Cart

CART, a vehicle mounted on two wheels, drawn by horses, used for the carriage of heavy goods. The word seems formed from the French *charette*, which signifies the same; or rather the Latin *caretta*, a diminutive of *carrus*. See CARR.

Mr. Sharp's *rolling cart* is fixed upon two rollers, running a-breast, or parallel with each other, and both placed under the body of the cart, working upon pivots like the wheel of a wheel-barrow. The rollers are both cylinders of cast iron, two feet diameter, and sixteen inches broad. An iron spindle passes through the centre of each roller, upon the ends of which rest the four planks that support the body of the cart. Criminals are drawn to execution on a cart. Bawds, and other malefactors, are whipped at the cart's tail.

Scripture makes mention of a sort of carts or drags, used by the Jews to do the office of threshing. They were supported on low thick wheels, bound with iron, which were rolled up and down on the sheaves to break them, and force out the corn. Norden and Niebuhr, in their "Travels," inform us, that this method of threshing is still practised in Egypt and Arabia. The former says that in Egypt they thresh, or rather tread, rice by means of a sledge drawn by two oxen, and that the man who drives them is upon his knees, whilst another has the care of drawing back the straw, and of separating it from the grain that remains underneath. In order to tread the rice they lay it on the ground in a ring, so as to leave a void circle in the middle. The Arabians, says the latter writer, in threshing their corn, lay the sheaves down in a certain order, and then lead over them two oxen, dragging a large stone. They use oxen in Egypt, he adds, as the ancients did, to beat out their corn by trampling upon the sheaves, and dragging after them a clumsy machine. This machine is not, as in Arabia, a stone cylinder; nor a plank with sharp stones, as in Syria; but a sort or sledge, consisting of three rollers, fitted with irons which turn upon axles. A farmer chooses out a level spot in his fields, and has his corn carried thither in sheaves upon asses or dromedaries: two oxen are then yoked in a sledge; a driver gets upon it, and drives them backwards and forwards, or rather in a circle upon the sheaves, and fresh oxen succeed in the yoke from time to time. By this operation, the chaff is very much cut down: the whole is then winnowed, and the pure grain thus separated. Something of the like kind also obtained among the Romans, under the denomination of *plaustra*, of which Virgil makes mention. Georg. I.

> *Tardaque Elusinæ matris volventia plaustra,*
> *Tribulaque, trabeæque*——

On which Servius observes, that *trabea* denotes a cart without wheels, and *tribula* a sort of cart armed on all sides with teeth, used chiefly in Africa, for threshing corn. The Septuagint and St. Jerom represent these carts as furnished with saws, insomuch that their surface was beset with teeth. David having taken Rabbah, the capital of the Ammonites, ordered all the inhabitants to be crushed to pieces under such carts, moving on wheels set with iron teeth; and the king of Damascus is said to have treated Israelites in the land of Gilead in the same manner. 2 Sam. xii. 31. Amos. i. 3. Calm. Dict. Bibl. tom. 1. p. 366.

CART, in *Agriculture*, is a carriage or vehicle constructed with two or more wheels, and drawn by one or more horses. It is employed for the purpose of conveying manure, hay, grain, and various other articles which are connected with the farm. Carts are made of different forms and dimensions, in some districts according to the nature of the materials they are intended to carry, and the uses to which they are applied; but by suitable contrivances they may be easily constructed, so as for the same cart to serve different uses. In the more southern parts of the kingdom this is mostly the case, by which there is not only a considerable saving, in fewer carts being wanted, but likewise in less room being taken up by them in the sheds or houses where they are kept. In these situations they are mostly formed in a close manner, having ladders or other similar contrivances applied when they are wanted to convey any of the more bulky sorts of materials, such as hay, straw, &c.

It is obvious that the chief object in the construction of carts should be to adapt the wheels and axle in such a manner, that the power may be applied in the most favourable direction for draught, and that the carriage may move with the least possible force. In this view the height of the wheels should likewise be well adapted to that of the animals which are employed in drawing them; but the exact heights which are the most favourable under different circumstances have not yet been fully shewn by any trials that can be fully depended upon. There is likewise another point which ought to be particularly considered in the making of farm-carts, which is, that they are not more heavy than is necessary; which is too often the case in the southern parts of the island. It has been remarked that the large heavy carts and waggons, which are so common in the southern districts, are not only reprobated, but almost wholly in disuse in those of the north, where small carts are in general use. Though there cannot be any doubt but that carts must vary in their forms, sizes, and modes of construction, according to the nature and situation of the roads, and many other local circumstances; yet for the purposes of farming, especially in field work, probably those of the light, single, and two horse kind may in general be the most advantageous, convenient, and useful.

It has been observed, in the twenty-seventh volume of the Annals of Agriculture, by lord Robert Seymour, that "the advantages of single-horse carts are, he believes, universally admitted, wherever they have been attentively compared with carriages of any other description. By his own observation he is led to think that a horse, when he acts singly, will do half as much more work as when he acts in conjunction with another; that is to say, that two horses will,

separately, do as much work as three conjunctively: this arises, he believes, in the first place, from the single horse being so near the load he draws; and, in the next place, from the point or line of draught being so much below his breast, it being usual to make the wheels of single horse carts very low. A horse harnessed singly has nothing but his load to contend with, whereas when he draws in conjunction with another, he is generally embarrassed by some difference of rate, the horse behind or before him being quicker or slower than himself; he is likewise frequently inconvenienced by the greater or lesser height of his neighbour: these considerations give, he conceives, a decided advantage to the sort of cart he is recommending." If any other is wanted, that "of the very great ease with which a low cart is filled may, he says, be added: as a man may load it, with the help of a long handled shovel or fork, by means of his hands only; whereas, in order to fill a higher cart, not only the man's back, but his arms and whole person must be exerted." To the use of single horses in draught he has heard no objection, unless it be the supposed necessity of additional drivers created by it: the fact however is, that it has no such effect; for, horses once in the habit of going singly, will follow each other as uniformly and as steadily as they do when harnessed together; and accordingly we see, says he, "on the most frequented roads in Ireland, men conducting three, four, or five, single horse cars each, without any inconvenience to the passenger: such likewise, is the case in this country, in which lime and coal are generally carried upon pack-horses, where one man manages two or three, and sometimes more." And in a preceding volume of the same work, Mr. Young is decidedly of the same opinion, which he clearly shews to be founded in truth, by entering into a variety of discussion in respect to the points in which they are preferable to tumbrils or waggons. In the northern districts they usually draw in these carts from twelve to twenty-four hundred weight, and where the roads are good, occasionally thirty, with much ease and facility.

And Mr. Donaldson, in his view of the "Present State of Husbandry in Great Britain," seems to think that, "for carrying on the ordinary operations of husbandry, carts drawn by two horses are greatly superior to large, cumbersome, unwieldy waggons, that require four, five, or six horses to move them along. It has of late," says he, "been a subject pretty much agitated, whether single-horse carts are not to as great a degree superior to those drawn by two horses, as these have been represented to be to waggons. Single-horse carts are certainly loaded and unloaded with much less trouble, and are in every way more easily managed, especially when carrying out dung, or when used for doing any odd jobs on a farm." It has also been found, from long experience and the most attentive observation, that "one horse will draw, on any road, two-thirds of the load that two horses, drawing in a line, and of equal power, are capable of doing. The carters of the town of Falkirk, in Stirlingshire, for example, have long been famous for the great weights drawn by their carts. Before the navigable canal between the Forth and Clyde was made, the whole goods transported to and from Glasgow, and the ports upon the Forth, were," says he, "drawn upon one and two-horse carts belonging to these carters; the most expert of whom have long given the preference to carts drawn by one horse, as they experience no difficulty in carrying upon a cart, drawn by a single horse, from Borrowstounness to Glasgow, a distance of upwards of thirty miles, and of indifferent road, from twenty to thirty-five hundred weight." It is, he observes, further worthy of remark, that "at the great iron-work at Carron, the company engaged in it formerly made use of waggons and waggon-ways, to wheel their coals and other heavy articles upon: but have entirely laid aside the use of them, and on principles of economy, employed carters with single-horse carts to transport the heavy articles which they require."

In the agricultural report of Northumberland it is likewise remarked, that "single-horse carts are becoming more prevalent in several parts of that county; and that Mr. James Johnson, a common carrier at Hexham, has a horse, sixteen hands high, that commonly carries from Hexham to Newcastle 24 cwt., and 20 cwt. back again; and there are instances of his having carried 26 cwt. from Newcastle to Hexham, which is a very banky, heavy-pulling road." It is also further noticed that "the neatest, most useful, and best contrived carts we know, are those made in many parts of the North-Riding of Yorkshire. The single-horse carts of this construction, used for carrying coals from the county of Durham into Yorkshire, are 60 inches long, 36 inches wide, and 18 deep, hold 24 bushels of coals, when set round the sides with large ones and upheaped. A man, or boy, drives three of these, two of which are equal to the greatest quantity ever carried by three horses." Mr. Charge of Newton, sends three of these carts for coals every day, which bring 72 bushels, the distance of 26 miles, there and back, which is performed in 12 hours by one man. The same gentleman's two-horse carts bring 36 bushels of the same coals.

And in the agricultural survey of Cumberland, the writers say, "the advantages of single-horse carts are so well understood in this county, that we did not see any other used. Three single-horse carts are driven without any difficulty, by a man, or boy, or even women and girls."

The author of the Agricultural Report of Mid Lothian, states, that "the wheel-carriages employed in husbandry are only the close-cart and the corn-cart, both of a light construction, drawn by two horses, and of late by one. The large wains, or heavy four-horse waggons, employed in English husbandry, are discarded there. Two horses in a cart are commonly loaded with 18 or 20 cwt. One horse draws still more easily 12 cwt.; even 24 cwt. is frequently put on a single horse; and 30 cwt. on good roads is not uncommon." And that "the first sort of cart has lately been much improved: when placed on its axle, the bottom at each side projects over the inner head of the naves as far as nearly to touch the spokes of the wheels; from which acquired breadth the capacity is enlarged; while the side-standards, being brought nearer to a perpendicular, are able to sustain more weight." The dimensions are, the length five feet three inches; the breadth below, four feet; the breadth above, four feet three inches; the depth, one foot three inches; containing about a cubic yard. The price of a cart, painted, 1l. 15s. not including wheels, axle, or mounting, which may amount in all to seven or eight pounds more. The wheels are generally 52 inches high, the axle commonly of iron, from an idea, that, in the end, it is more economical to have them so: for it is not found in practice that iron axles are either more or less difficult to draw, although not half the thickness, of those of wood."

It has been suggested on the ground of much experience, that, in constructing carts of this sort, the capacity of waggons is by no means an accurate rule to proceed by; as on finding that they contained in the bed, or *buck*, ninety-six cubical feet, being twelve feet long, four feet wide, and two feet in depth; it was supposed that to give one horse the fourth part of the load of four, it would only be necessary to let the cart have the space of twenty-four cubical feet, or

to make it four feet by three, with the depth of two; but from the vast superiority of horses working singly, over those in teams, it was soon discovered, that they required to be very considerably enlarged, admitting of having the dimensions of five feet one inch in length of bed or *buck*, three feet seven inches in breadth, with two feet in depth; so as to contain thirty-five cubical feet and a fraction. This, therefore, affords a further striking proof of the great superiority these small carts have over those of the large kind, in the quantity of work which they are capable of performing.

In speaking of the advantage of having low cast-iron wheels, it is remarked by lord Seymour, in the paper just mentioned, that "the price of iron, cast into wheels, is 16s. per cwt., and the weight of each wheel about three quarters of a cwt. Two inconveniences only, he believes, have been found from the use of low cast iron wheels: the first is, that cast-iron is very liable to breakage, upon concussion; the next is, that the course of so small a diameter creates a very quick consumption of grease. The first of these objections is in a degree removed by the ease with which the rim of the wheel is repaired by the application of worked iron, which being joined to it by a rivet, the wheel acquires some little elasticity, and thereby becomes perhaps stronger than when it was new. In order that the supply of grease may keep pace with the consumption, he has introduced four grooves, or cavities, in the boxes, increasing a little towards their centres; and in order to defend the axle-tree, which consists of worked iron, against the harder body of the box, he has steeled the extremity of it."

These small carts are considered by many, from actual experience, to be better adapted to the carrying of all sorts of materials except those of the very bulky kinds, and such as trees, blocks of stones, &c. the weights of which might injure them, and which cannot from their nature admit of division. In all hilly districts where the roads are of an inferior kind, and the inhabitants poor, these are the carts that are in most general use, and which are found the most advantageous. The superior goodness of the roads in some of the northern parts of the kingdom have likewise been ascribed to the use of these kinds of carts, as large carriages of all sorts that require the wheels to be locked in descending hills, are the destruction of roads.

By the author of the New Farmer's Calendar it is stated that "of the great saving to be made by one-horse carts there can be no doubt, since it has been experimentally proved, and was moreover, easily to be discovered from just theory. More weight may be drawn by six horses in so many carts, than by eight in a large waggon; and one man may manage two carts in the country." There are, however, he thinks, "some peculiar inconveniences attendant upon this plan, which are sufficiently obvious; and, says he, notwithstanding it has been, for years past, so warmly recommended by very powerful pens, it never has, nor probably ever will be, relished by the generality of farmers."

After this view of the nature of carts in general, and of the particular advantages of single-horse carts; it may be useful to describe the different sorts of carts that are employed in the business of husbandry.

Close cart, a name given to all such carts as have no ladders, rails, or wings, attached to them. They are made close by boards, and mostly employed in conveying dung, gravel, earth, or such other materials as have considerable weight, in a small compass. By the application of wings or ladders to them, they are however, frequently made to serve the double purpose of conveying heavy close matters as well as those of a light bulky nature. This sort of cart is represented at *fig.* 3. *Plate* III. of *Agriculture*.

Corn cart, is that sort of cart which is only placed occasionally on wheels, for carrying hay, corn in the straw, or other light bulky articles; carts of this kind are generally composed of standard rods, and spars, without deals, but broader and much longer than the close cart, that they may hold a more bulky load. They cost from 20s. to 30s. in Scotland, but in England they are considerably higher. They are commonly employed in the northern parts of the kingdom for carrying hay, grain in the straw, and other similar bulky materials. A cart of this sort is shewn at *fig.* 4. *Plate* III.

Coup cart, a cart of the close kind, so denominated from the body-part resting on a sort of frame, to which it is kept by means of staples, or other contrivances, through which a cast-bar, or wooden pin, is put, by which it is confined, and which can be readily removed when the load is to be either partially or wholly discharged. Carts of this sort are generally used in putting dung upon land, and are convenient for many other purposes in husbandry. See *fig.* 3. *Plate* III.

Drag cart, a sort of cart invented by lord Sommerville, which is constructed with a drag, or some other contrivance, for checking, or regulating the rapidity of the motion in going down hills, or other declivities. A full account of this cart has been given in the second volume of "Communications to the Board of Agriculture." At *fig.* 5. in *Plate* III. is a perspective view of a cart of this sort to be drawn by two strong oxen, by a pole, yoke, and bows, made to carry 45 cwt. In the front of this *figure* is represented the method which his lordship has contrived for adjusting the position of the centre of gravity of the load, to prevent its pressing too much on the cattle in going down hill, the front of the cart being elevated by means of a toothed rack screwed to the front of the cart, and worked by a pinion, and the handle, *a*, immediately connected with the pole, *e*. By means of this pinion and rack, the front of the carriage is elevated more or less, in proportion to the declivity of the hill, by which means the weight of the load is made to bear more on the axis, and less on the necks of the oxen.—On the side view of this cart is represented the manner of applying the friction-drag, which is made to press more or less on the side of the wheel, according to the steepness of the descent:—*bb* is the friction-bar, or drag, the one end of which is connected with the tail of the cart by a small chain, and the other end to the front, by means of a toothed rack, *bd*, which catches on a staple in the front of the cart, by which the friction-bar may be made to press on the side of the wheel, more or less, at the discretion of the driver: the notches or teeth in this rack, it is observed, should be as close to each other as circumstances will permit. And in this representation, the friction-bar is, he remarks, applied lower upon the wheel than was at first proposed, in order to divide the pressure and friction more equally on the opposite sides of the wheel, so that the pressure on each is diminished, the risk of over-heating and destroying the friction-bars is also rendered less, than if the whole pressure was applied in one point on the top of the wheel. The weight of the iron-work of this cart is 2 cwt. 20 lb. This is unquestionably an useful contrivance for hilly districts. At *fig.* 5. in the same *Plate*, is a side view of a cart of this kind of a smaller size, to carry 25 cwt. and to be drawn by steers, or small oxen, with the friction-drag, *bb*, out of use; and representing another and more simple method of adjusting the centre of gravity of the load to the declivity of the descent: *ab* is part of the arch of a circle, whose radius is nearly equal to its distance from the axis of the cart, and having several holes in it, through which a strong iron pin is put, to keep

the body of the cart at any desired inclination with the pole:—*c*, a small chain to prevent the body of the cart being thrown too far back, through the carelessness of the driver in adjusting it:—*dd*, the upper stage of the cart, for carrying bulky loads.—The weight of iron in this cart is 1 cwt. 30 lb. This is a very useful, neat, light sort of cart for many purposes.

The advantages of the friction-drag, and other contrivances in this cart, according to the ingenious account of Mr. Cumming, contained in the same volume, are,

"1. The method, which is equally simple and expeditious, of adjusting the centre of gravity of the load, so as to have a proper bearing on the horses or cattle in going down hill, the advantage of which must be obvious to every man of science, more especially with bulky loads, in which the centre of gravity lies high.

2. The method of applying friction to the side of the wheel to regulate the motion of the carriage in going down hill (instead of locking the wheels), the advantages of which method appear to be as follow: namely, 1st. The pressure and degree of friction may with great expedition be adjusted to the steepness of the declivity, so that the carriage will neither press forward, nor require much exertion to make it follow the cattle. 2dly. The friction is so applied to the wheel, that a given pressure will have twice the effect in retarding the progress, that it would have if immediately applied to the body of the carriage, or to the axis: and by applying the friction on both sides of the wheel, the risk of heating and destroying the friction-bar is much less than if the same degree of friction was applied in one place. 3dly. This apparatus is so conveniently placed, that it can be instantly applied or adjusted, without stopping the carriage, or exposing the driver to the same danger as in locking a wheel. And, 4thly. This useful contrivance, in which he says simplicity and ingenuity are so happily blended, will assume yet greater importance when applied to both the hind wheels of waggons, by which means the resistance may always be proportioned to the steepness of the descent, the tearing up of the road prevented, the unnecessary exertion of the cattle in drawing the locked carriage down hill avoided, the danger to which the driver is sometimes exposed in locking the waggon wheel totally avoided, and the time now lost in locking and unlocking the wheel saved to the proprietor." These are certainly advantages of much importance in many districts where the roads are hilly.

At *figs.* 7 and 8 in the same *Plate* are views of carts to be drawn by a single horse, by shafts. By an attentive comparison of those drawn by shafts, with those that are drawn by the yoke and bows, the superiority of the pole to the shafts, and the advantage of making the cattle to draw by the yoke in preference to drawing by the forehead, become evident. When cattle draw by the shafts, says his lordship, the one before the other, it is impossible for the driver to know that each exerts an equal force, so as to contribute equally to the draught; but when they draw by the pole and yoke, the point of draught being in the middle of the yoke, when the beasts draw equally, the yoke will stand square with the pole, and the position of the yoke will always enable the driver to discover the defaulter, and to bring him to a proper exertion: it is, he says, this harmony of draught, and equality of exertion, that gives so great advantage to drawing by the yoke, that it is scarcely possible to say what weight of load two good large oxen can draw on a level road." The powers of cattle drawing by the forehead, on lord Shannon's estate, are recorded by Mr. Young and Mr. Billingsley:—an ox of the late Mr. Tattersall, near Ely, drew four tons of wood on a level surface without apparent difficulty. What then, says he, "might not be expected from the equal exertion of two such powerful animals, acting at the equal ends of the same yoke?" Notwithstanding these judicious observations, further trials are wanting with respect to the best modes of draught.

Hay Cart, a cart made use of for conveying hay from the field; it is constructed in the same way as that made use of for corn. See *Corn Cart*.

Quarry Cart, is a stiff, strong sort of cart, employed in quarries. Carts for this purpose are variously constructed, according to the nature of the materials to be conveyed by them. When flat stones of great length and breadth are to be carted, they should be low, for the convenience of loading and unloading, and at the same time very firmly put together.

It is stated in the Agricultural Survey of the County of Perth, that "Mr. Mylne, of Mylnfield, employs a cart of a particular construction in his quarry of Kingoodie, which merits the attention of those who have works of a similar nature. This cart has a bend in the axle, which brings it within fourteen inches of the ground, although moving on wheels more than five feet high. The ease with which it is drawn, loaded, and unloaded, is superior to the common cart, in the proportion of 7 to 3." It is seen at *fig.* 9. in *Plate* III. He also uses in this quarry "a cart for carrying very large stones, such as mill-stones, &c. which is drawn as easily upon wheels of two feet two inches in height as upon wheels of a greater diameter. In this cart the axle is only about five feet long, so that the wheels run under the body of the frame, which is flat, and may be made of any breadth or length required."

Single horse Cart, that light sort of cart in which only one horse is employed. The term is made use of to distinguish them from those of the large kind, in which three, four, or even a greater number of horses are made use of. Carts of this small construction are extremely useful for all the various little purposes of cartage about the farm, as has been fully shewn above. See *figs.* 3. 7. and 8. in *Plate* III.

Three wheel Cart, a kind of cart that is constructed with three wheels, one being commonly placed in the middle, before, and generally of a smaller size. Carts of this sort are mostly close, and used when great quantities of earth or other materials are to be conveyed at once to some distance.

Carts, *laws relating to*. By 13 Geo. III. c. 78. no cart, having the sole or bottom of the fellies of the wheels of the breadth of nine inches, shall be drawn with more than five horses; and no cart, having the said sole the breadth of six inches, shall be drawn with more than four horses; and those of less breadth than six inches shall not be drawn with more than three horses, under a penalty on the owner of 5l., and on the driver (not being the owner) of 10s. for every horse above the stipulated number: the information to be laid within three days and the action commenced within one calendar month after the offence committed. Exceptions are admitted in favour of carriages, moving upon wheels or rollers of the breadth of 16 inches on each side, with flat surfaces, and such as justices allow by licence to be drawn up steep hills, or on roads that are not turnpikes, or in deep snow or ice, or carrying any one stone, block of marble, cable rope, piece of metal, or ammunition and artillery for his majesty's service. Two oxen or horned cattle are considered in the contemplation of this act, as one horse. Moreover it is enacted by 6 Geo. I. c. 6. that no person in London and Westminster, or within

10 miles, ſhall carry at one load in carts or waggons having their wheels ſhod with iron, more than 12 ſacks of meal of five buſhels each, nor more than 12 quarters of malt, nor more than 750 bricks, nor more than one chaldron of coals, on pain of forfeiting any one of the horſes, with geers, bridles, &c. And by 18 Geo. II. c. 33. wheels of every cart, car, or dray, within the bills of mortality, ſhall be ſix inches broad in the felly, and not wrought about with iron, nor be drawn with more than three horſes, after they are up the hills from the waterſide, under a penalty of 40s.; but this act does not extend to any country cart or waggon, that ſhall bring any goods, or ſhall carry any goods half a mile beyond the paved ſtreets of the ſaid cities and places. Any perſon, within the ſaid limits, uſing any cart, car, or dray, having the wheels full ſix inches broad, when worn, may have the ſame bound round with tire of iron, provided it be ſix inches broad, and made flat, and not ſet on with roſe-headed nails. No perſon ſhall drive any cart, within the ſaid limits, unleſs the name of the owner, and number of ſuch cart, &c. be placed in ſome conſpicuous place of the cart, &c.; and his name be entered with the commiſſioners of hackney-coaches, under the penalty of 40s. and every perſon may ſeize and detain ſuch cart till the penalty be paid. On changing property, the names of the new owners are to be affixed, and to be entered with the commiſſioners of hackney-coaches, 30 Geo. II. c. 22. And ſtat. 24 Geo. III. ſt. 2. c. 27. compels the entry of all carts driven within five miles of Temple-bar. By 13 Geo. III. c. 78. §. 11. a perſon, who leaves any cart or other carriage, &c. in any high-way, beyond the reaſonable time allowed for loading or unloading, ſo as to obſtruct the paſſage of any other carriage, &c. ſhall forfeit 10s. By 1 Geo. ſtat. 2. c. 57, by 24 Geo. II. c. 43, and, more generally, by 13 Geo. III. c. 78, it is enacted, that if the driver of any cart, car, dray, or waggon, ſhall ride upon any ſuch carriage in any ſtreet or highway, not having ſome other perſon on foot or on horſeback to guide the ſame (ſuch carriages as are conducted by ſome perſon holding the reins of the horſe or horſes drawing the ſame excepted);—or if the driver of any carriage whatſoever, on any part of any ſtreet or highway, ſhall by negligence or wilful miſbehaviour cauſe any hurt or damage to any perſon or carriage paſſing or being upon ſuch ſtreet or highway;—or ſhall quit the highway and go on the other ſide of the hedge or fence incloſing the ſame; or wilfully be at ſuch diſtance from ſuch carriage, whilſt it ſhall be paſſing upon the highway, that he cannot have the direction and government of the horſes or cattle drawing the ſame: or ſhall, by negligence or wilful miſbehaviour, prevent, hinder, or interrupt the free paſſage of any other carriage, or of his majeſty's ſubjects, on the ſaid highways; or if the driver of any empty or unloaded waggon, cart, or other carriage ſhall refuſe or neglect to turn aſide and make way for any coach, chariot, chaiſe, loaded waggon, cart, or other loaded carriage; or if any perſon ſhall drive, or act as the driver, of any ſuch coach, poſt chaiſe, or other carriage let for hire, or waggon, wain, or cart not having the owner's name (as by this act is directed) painted thereon, or ſhall refuſe to diſcover the true chriſtian and ſurname of the owner of ſuch reſpective carriage; he ſhall on conviction by confeſſion, view of the juſtice, or oath of one witneſs, before one juſtice, forfeit any ſum not exceeding 10s., in caſe ſuch driver be not the owner of ſuch carriage; and if he be the owner, then any ſum not exceeding 20s.; and in default of payment be committed to the houſe of correction for any time not exceeding one month, unleſs the ſame be ſooner paid. And every ſuch driver offending in either of the ſaid caſes, may by authority of this act, with or without any warrant, be apprehended by any perſon who ſhall ſee ſuch offence committed, and ſhall be immediately conveyed or delivered to a conſtable or other peace officer, to be conveyed before a juſtice, to be dealt with according to law. And if any driver, in any of the caſes aforeſaid, ſhall refuſe to diſcover his name, the juſtice may commit him to the houſe of correction for any time not exceeding three months, or may proceed againſt him for the penalty by a deſcription of his perſon and the offence, and expreſſing in the proceedings that he refuſed to diſcover his name.

And for the better diſcovering of offenders, the owner of every waggon, wain, or cart, and alſo of every coach, poſt chaiſe, or other carriage, let to hire, ſhall cauſe to be painted, upon ſome conſpicuous part of his waggon, wain, or cart, and upon the pannels of the doors of all ſuch coaches, poſt chaiſes, or other carriages, before the ſame ſhall be uſed in any public highway, his chriſtian and ſurname and place of abode, in large legible letters; and continue the ſame thereupon ſo long as ſuch carriage ſhall be uſed upon any highway: and the owner of every common ſtage waggon or cart ſhall, over and above his chriſtian and ſurname, cauſe to be painted on the part and in the manner aforeſaid, the following words, *common ſtage waggon or cart*, as the caſe may be. And every perſon uſing any ſuch carriage as aforeſaid upon any highway, without the ſaid names and deſcriptions reſpectively, or cauſing to be painted thereon any fictitious name or place of abode, ſhall forfeit not exceeding 5l. nor leſs than 20s.

"Taxed carts," conſtructed, kept, and uſed under the regulations of the ſtat. 43 Geo. III. c. 99, are exempted from the annual duty of 5l. 5s. charged for carriages with leſs than four wheels and drawn by one horſe. Such carriages are thus deſcribed: they ſhall be built wholly of wood or iron, without any covering other than a tilted covering, and without any lining or ſprings, made of iron, wood, leather, or other materials, and with a fixed ſeat, without ſlings or braces, and without any ornament whatever, other than paint of a dark colour, for the preſervation of the wood or iron only, and which ſhall have the words "a taxed cart," and the owner's chriſtian and ſurname and place of abode, marked or painted on a black ground in white letters, or on a white ground in black letters, on the outſide of the back pannel or back part of ſuch carriage, in words at full length, and of a breadth in proportion, and the price of which (repairs excepted) ſhall not have exceeded, or the value thereof ſhall not at any time exceed the ſum of 12l. ſterling. For ſuch a carriage kept by any perſon for his own uſe, and not for hire, the annual duty to be paid is 1l. 4s. The exemption from all duties ſpecified in the foreſaid act extends to any cart kept to be uſed wholly in huſbandry, or in the carriage of goods in the courſe of trade, and whereon the name and reſidence of the owner, and the words "common ſtage cart" ſhall be legibly painted; although the owner, or his or her ſervant, ſhall occaſionally ride therein or thereon when laden, or when returning from any place to which, or when going to any place from which any load ſhall have been or ſhall be to be carried in ſuch carriage, or for conveying the owners thereof or their families to or from any place of divine worſhip on Sunday, or on Chriſtmas-day, or on Good Friday, or on any day, appointed for a public faſt or thankſgiving, or for carrying perſons going to or returning from the election of members to ſerve in parliament.

Casting

CASTING, in *Foundery*, is the running of a melted metal into a mould prepared for that purpofe.

The great importance of a knowledge of cafting to a mechanic, on account of the vaft quantities of caft-iron now ufed in machinery, has induced us to give a particular defcription of this branch of the founder's art.

There are three forts of cafting, 1. *open fand cafting;* 2. *fand cafting between flafks;* and 3. *loam-cafting;* in moft of which, an exact pattern, ufually of wood, of the fubject to be caft, is given to the founder.

I. Moft articles, every part of whofe furface on one fide is in the fame plane (which we will call the horizontal plane), and every parallel fection of which is of the fame fize in every part as the horizontal plane, or conftantly decreafing as they recede downwards from it, and the edges of all which fections fall within perpendiculars, let fall from the edges of the plane immediately above it, may be caft in *open fand:* becaufe, as the founders exprefs it, every fuch pattern will *lift* out of the fand, wherein it has been imbedded as deep as its upper or plane furface, to form the mould for the metal.

The floor of every foundery is for many feet deep compofed of a loamy fand (of which great quantities are brought to London from near Woolwich) fo that deep pits may be dug, to bury large moulds in. (See FOUNDERY). An example of open fand-cafting is fhewn in *Plate* of *Cafting, figs.* 1 and 2, which reprefent the arms of a large wheel, the rim of which is to be fcrewed on by the flaunches *a, a, fig.* 1.; *b b* is the arm; *d* is a rib caft with it to ftrengthen it, the other fide of the arm muft be plain; *e* is the opening through which its fhaft is to pafs. In the place where the mould is to be made, a layer of fand, *c d, fig.* 2, is lightly fprinkled through a fieve on the floor, and the pattern A is preffed down into it, perfectly level; the next operation is fhovelling the fand up all round, level with the top of the pattern, and ramming it down, with a tool, *fig.* 4.; a fponge is then ufed for flightly wetting the fand all round the edges of the pattern to make it adhere together; the next operation is lifting the pattern out of the fand by one or more fcrews, *fig.* 5, fcrewed into the wood; if the pattern is fmall, this is done by one or more men, but in very large works it is done by a crane; the cores for the bolt holes through the flaunches, *a, a, fig.* 1. are made by fticking pieces of dried clay in the fand in the proper places, and the core for the hole *e*, made of clay, is alfo fet in its place; the workman then ufes a pair of bellows for blowing away any fmall pieces of fand which may have fallen into the mould. It is now ready for filling with metal; in fmall works this is done by ladles, and in large, by fmall ditches made in the fand, from the mould to the mouth of the furnace: when the mould is filled, the metal is covered up with fand to keep the air from it.

II. *Sand-cafting* between flafks is ufed for thofe articles which if they were cut into two or more pieces (provided the cutting planes were parallel to each other) each feparate piece might be caft in open fand. A fpecimen of this fort of cafting is fhewn in *fig.* 6, which is an endlefs fcrew and fpindle, often compofed of caft iron. AB and CD are frames called flafks, with four handles, *c, d, e, f,* to lift by; *a, b, l, m,* are iron points fitting into holes *g, h, i, k,* in the other flafk CD, for afcertaining when they fit each other. The under flafk CD is fet upon a board, filled with fand, and the fame is rammed tight into it: the workman then takes the pattern EF, and preffes one half of it into the fand, and fmooths the fand up to the fides of the pattern with a trowel, *fig.* 3; he then fets the empty flafk, AB, over the other, CD, putting its points *a, b, l, m,* into the holes *g, h, i, k;* and after fprinkling fome fand which has been burnt over the fand in the under flafk, he fills the upper one with fand, and rams it down; he next with a piece of wood, put through the fand in the upper flafk, makes a hole fhewn at *p*, to pour the metal through; the upper flafk, AB, with the fand in it, is then lifted off by men, or in large works, by a crane, and the pattern, EF, lifted out; the flafk, AB, is then put on again, and heavy weights are laid on it to keep it down, ready for cafting. It muft be obferved, that at every higheft point of large moulds a fmall hole muft be made through the fand in the upper flafk, to allow the air to pafs out of the mould when the metal is poured in.

Figs. 7, 8, 9, and 10 fhew the manner of cafting a cog-wheel with eight arms, all of which are ribbed on both fides. The pattern is laid upon a board with the face fhewn in *fig.* 7, upwards; an empty flafk is laid upfide downwards over the board and pattern; it is filled with fand and rammed tight; a plain board is then laid upon the flafk, and two men turn it over, bringing the pattern to the top, as fhewn in *fig.* 10; the workman with a fmall trowel, *fig.* 3, then digs all the fand out of the fpace AA, *fig.* 10, between each arm, leaving it level with the tops of the ribs, *a b, c d,* &c. *fig.* 7; into each of the fpaces thus formed, a piece of iron plate, *fig.* 8, cut to fuit the fame, is laid; it has an iron rod, *a*, projecting from the upper fide and two points, *b, d,* at the under fide, which are inferted into the fand between the arms, fo that the two edges, *e, f,* touch the upper edge of the arms *a, b,* of the wheel, *fig.* 7. The fpaces above thefe plates are then filled with fand and rammed down level with the reft of the fand in the flafk: burnt fand is then fprinkled over the lower flafk to prevent the fand which is now to be rammed into the upper flafk, CD, from adhering to that in the lower; the holes for the metal are next made through the top flafk, and it is then taken off; the iron plates and the fand upon them are taken out by the ends of the iron, *a*; the fand round the pattern is flightly wetted, and the cogs of the wheel are taken out one by one (for which purpofe they are only fixed on by a dovetailed groove cut in the rim, fee M) and then the whole wheel is lifted out by the fcrews, *fig.* 5; the iron plates

plates are then put again in the place where they ſtood before, being determined by the holes which the points, *b*, *d*, made in the ſand. The hole H through the wheel, which is to receive the ſhaft, is ſolid in the pattern, and a projection of the ſame ſize as the intended hole is fixed on; this projection forms a receſs, *k*, *fig.* 10, in the ſand, which is to determine the place of the core, M, *fig.* 9, for the hole which is made in a ſeparate pattern of well tempered clay or wet loam and dried. The upper flaſk, C D, is then put on again, and loaded with weights ready for caſting. In caſting large cog-wheels, &c. flaſks are often wanted as large as 20 feet on each ſide; to keep the ſand from falling out, bars of wood are bolted acroſs the flaſk, into which long nails are driven, before it is filled, to keep the ſand together. Theſe large flaſks are lifted by a crane.

III. *Loam-Caſting* is uſed for bulky articles, as cylinders, large pipes, boilers, cauldrons, &c. &c. We will begin by deſcribing the manner of forming the mould for a large cylinder: A, *fig.* 11, is a beam of the building; B B is a ſpindle with three or four holes, *d c*, through it, to fix an iron arm D in, at different heights by a nut; E E is a board, that can be firmly fixed between the bars D and F, by two clamps, G, H: the operation is begun by laying an iron ring L upon the ground, and adjuſting it ſo as to be concentric to the ſpindle B; a cylinder of brick-bats and clay or wet loam, inſtead of mortar, is then built upon it, ſome inches leſs in diameter than the intended cylinder, for which this is to form a core; the bricks are ſtrongly bound together with iron hoops, nealed wire, &c. and a fire is then lighted in it. When the loam uſed with the bricks is dry, a coating of loam is ſpread over it, and is ſmoothed by turning the board E E round it. This coat makes it of the proper ſize for the inſide of the cylinder to be caſt, and is called the core of the mould; another cylinder is built, plaiſtered, and ſmoothed in the ſame way, except that no hoops are uſed, whoſe diameter is the ſame as the outſide of the cylinder to be caſt; when it is finiſhed, it is covered with charcoal ground with water like paint, laid on with a bruſh; and a thin coating of loam is laid on; this is bound round with hoops, and to theſe, four hooks are fixed to lift it by; a thick coat of loam and hair is then laid over it. When all theſe are dry, a man gets into the cylinder, and with a ſmall pick pulls down all the bricks in the inſide cylinder, and then with a trowel cuts away all the loam, leaving the inſide of the external cylinder (which is called the mould) quite ſmooth; this is effected by the coat of charcoal, which prevents the two coats of loam from adhering together.

A deep pit is now dug, in ſome convenient part of the foundery, into which the core is let down by a crane; an apparatus, ſhewn in *fig.* 12, is uſed for flinging it to the crane, A B D E is a wrought-iron croſs, the arms of which are ſtrengthened by ties going through the ring F, by which it is hooked to the crane-rope or chain; on each of the four croſs-bars, a ring with a hook, *a b d e*, is looſely fitted; to theſe hooks ropes which paſs through the hooks on the mould are faſtened, in the core theſe ropes go round the ſtubbs, *l*, *l*, of the ring L, *fig.* 11. The mould can always be made to hang perpendicularly, by ſliding the hooks, *a*, *b*, *c*, *d*, nearer to or farther from the center of the croſs. When the core is ſet down in the pit, the mould is let down over it by the ſame means, and when they are adjuſted, the ſand is thrown in, and rammed round, about half the height; a flat cover of dried loam is then put on the top of the mould and core, and round pieces of wood are put in the holes which had before been made in the cover for pouring the metal in at. The burying of the mould is then completed: when it is all levelled. The ſticks which keep open the holes for the metal are carefully pulled out, and ſmall ditches made from the furnace to them, ready for caſting.

Fig. 13, ſhews the method of making the mould for an air-veſſel (ſee our article PUMP); the core, A, is built of bricks, plaiſtered with loam and turned by the machine, *fig.* 11, as before deſcribed; the edge of the board, E E, being cut to the proper curve; another is then built of the ſame ſize and form as the outſide of the veſſel to be caſt, with a projecting ring or flaunch at the bottom; this, after being turned, is painted with charcoal, and the mould made upon it as in the laſt caſe; it is plain, that from the ſhape of the core the mould cannot be lifted off, nor can a man readily get in, to take out the bricks as in the caſe of a cylinder; the mould muſt therefore be ſawn in half, B G, with a fine ſaw, to get it off; it is then put together again round the core A, and the crack is plaiſtered up with loam. To deſcribe the more complicated caſes of this kind of Caſting, as the nozzles or valve-boxes and pipes of ſteam-engines, &c. &c. would far exceed our limits.

CASTING *of gold*, *ſilver*, or *copper*, in plates. See COINING.

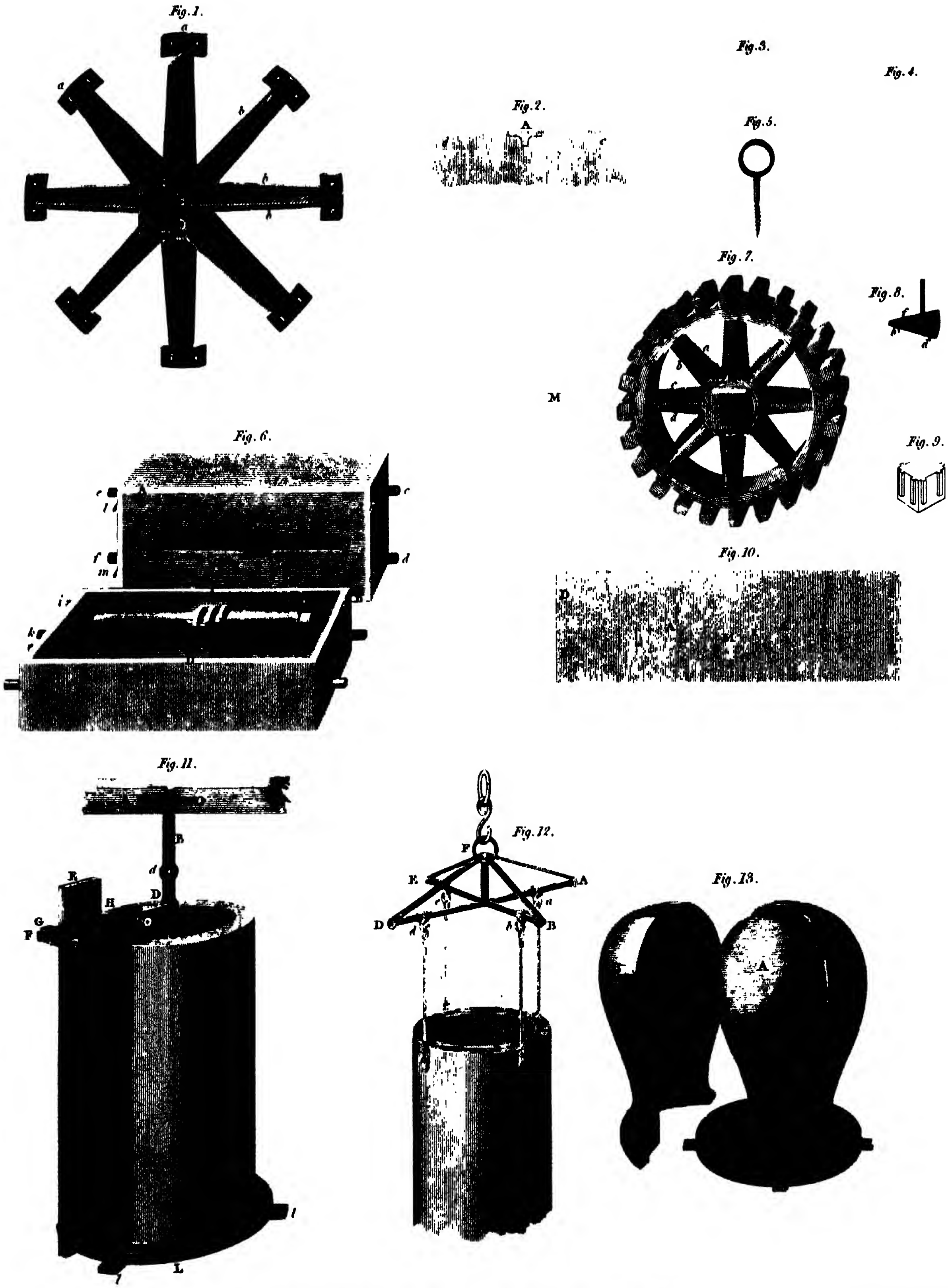
CASTING, in *Joinery*, &c. Wood is ſaid to be *caſt* or warped, when, either by its drought or moiſture, or the drought or moiſture of the air, or other accident, it ſhoots or ſhrinks; in prejudice to its flatneſs or ſtraitneſs.

CASTING *of lead on cloth*, is the uſing of a frame or mould covered with woollen cloth and linen over it, to caſt the lead into very fine ſheets.

CASTING *of lead on ſand*, is done by means of a large frame or trough nearly full of ſand, which is made perfectly level, and imprinted with any device from moulds preſſed down in the ſand: the lead is then turned out of the kettle into a receiver or trough, and poured on the ſand, whilſt two perſons ſlide a gauge or lath, of ſuch thickneſs as to leave a ſpace between it and the ſand anſwering to the ſubſtance of the lead, along the edges of the frame; the ſurplus runs into reſervoirs by channels made in the ſand. See CASTING, in *Foundery*.

The goldſmiths uſe the bone of the CUTTLE-*fiſh*, to mould and caſt their leſſer works of gold and ſilver; that bone, when dried, being reducible to a kind of a fine pumice, very ſuſceptible of all impreſſions.

CASTING *in ſtuc* or *plaiſter*, is the filling with fine liquid plaiſter a mould that had been taken in pieces from off a ſtatue or other piece of ſculpture, and run together again. There are two things to be obſerved with regard to the mould: the firſt, that it be well ſoaked with oil before the plaiſter be run, to prevent its ſticking: the ſecond, that each piece whereof it conſiſts have a packthread, to draw it off the more eaſily when the work is dry. See CAST.



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Addenda & Corrigenda.

ACETIC Acid. It is now univerſally admitted by chemiſts, that the acetic acid differs in no reſpect from common vinegar, or what was formerly termed *acetous* acid, but in the degree of concentration only. This opinion, firſt advanced by Adet, has lately been fully confirmed by the experiments of Darracq and Prouſt. What has been ſaid, therefore, on the ſubject of *acetous* acid and *vinegar* in the Cyclopædia, is to be underſtood as applicable to dilute *acetic* acid; and the ſalts termed *acetites* are to be conſidered as *acetates*. The following facts are important, and deſerve a place here.

The ſpecific gravity of acetic acid does not enable us to determine its ſtrength. The ſpecific gravity is ſtated by Dr. Thomſon to be a maximum when the liquid is a compound of one atom, and three atoms water. When the proportion of water is either increaſed or diminiſhed, the ſpecific gravity diminiſhes. Acid compoſed of one atom real acid and one atom water, and acid compoſed of one atom real acid and nine and a half of water, are ſtated by the ſame chemiſt to have the ſame ſpecific gravity.

The following table, drawn up chiefly from the experiments of Mollerat by Dr. T., exhibits the ſpecific gravity of acetic acid of various ſtrengths.

Atoms. Acid.	Atoms. Water.	Weight of Acid.	Weight of Water.	Sp. Gr.
1 +	1	100	14.78	1.0630
	2	100	25.21	1.0742
		100	37.99	1.0770
	3	100	48.43	1.0791
		100	52.94	1.0800
		100	59.38	1.0763
	4	100	71.90	1.0742
	5 −	100	83.90	1.0728
	6 +	100	116.25	1.0658
	7	100	127.73	1.0637
	9½	100	166.34	1.0630

Acetic acid of the ſp. gr. 1.063 is the ſtrongeſt that can be procured. It cryſtallizes at the temperature of 55°, and the cryſtals melt ſlowly when heated to 72½°. This had been long ago obſerved by Courtenvaux. Lowitz has propoſed an ingenious method of obtaining it of the requiſite degree of ſtrength to cryſtallize. This conſiſts in making diſtilled vinegar into a thick paſte with well-burnt charcoal, and expoſing the mixture to a temperature of 212°. The watery part is driven off, and the acid remains. The acid itſelf may be ſeparated by a higher degree of heat, and thus obtained in a very concentrated ſtate. It is commonly neceſſary, however, to repeat the proceſs before it can be made to cryſtallize.

Mr. Chenevix, by diſtilling the *acetates*, obtained a peculiar ſubſtance different from acetic acid, and which he has denominated *pyro-acetic* ſpirit. The acetates of potaſh and ſoda gave a greater proportion of this principle than any of the metalline acetates; but when the acetate of barytes is diſtilled, the whole liquid product conſiſts of this ſpirit without any mixture of acid whatever. No other genus of ſalts tried, ſuch as the oxalates, tartrates, or citrates, yielded this ſpirit, nor was acetic acid converted into it by heat.

Pyro-acetic ſpirit is a white and limpid fluid. Its taſte is at firſt hot and acrid, but it becomes cooling and rather urinous. Its ſmell is peculiar, and is compared by Mr. Chenevix to that of a mixture of oil of peppermint and bitter almonds. Its ſpecific gravity is .7864. It burns with a flame, white exteriorly, but of a fine blue within, and leaves no reſidue. It boils at a temperature of 165°. It mixes with water, alcohol, and volatile oils, in any proportion. With hot olive-oil it alſo mixes in any proportion; but with that oil cold it only mixes in certain proportions. When hot it diſſolves wax and tallow. It diſſolves alſo a little ſulphur and phoſphorus, and is an excellent ſolvent of camphor. It diſſolves potaſh, and becomes dark-coloured, but it may be obtained again unaltered by diſtillation. Strong ſulphuric acid blackens and decompoſes it. Nitric acid renders it yellow, and changes its properties. Muriatic acid renders it brown. When diſtilled with this acid a combination takes place, and a ſubſtance is formed poſſeſſing very different properties from muriatic ether. Theſe properties are ſufficient to ſhew, that the pyro-acetic ſpirit is a diſtinct ſubſtance, and differs entirely from alcohol, ether, and volatile oils. Of courſe, therefore, as Dr. Thomſon obſerves, it deſerves a diſtinct place among compound combuſtibles.

Many attempts have been made to analyſe the acetic acid. Thoſe moſt worthy of notice are by Gay Luſſac and Thenard, and Berzelius. The former burnt a mixture of acetate of barytes and chlorate of potaſh. The reſults were carbonic acid and water. Berzelius's analyſis was made on the ſame principles, but the ſalt he employed was ſuppoſed to be quite free from water. The following are the reſults of theſe celebrated chemiſts:

	Hydrogen.		Carbon.		Oxygen.		Acid.
Gay Luſſac	5.629	+	50.224	+	44.147	=	100
Berzelius	6.35	+	46.83	+	46.82	=	100

If, with Dr. Thomſon, we conſider the reſults of Berzelius moſt entitled to credit, acetic acid conſiſts of

3	atoms or proportions of hydrogen,	weighing	0.375
4	——— of carbon	———	3.000
3	——— of oxygen	———	3.000

Or of ten atoms or proportions, and the weight of an integrant particle, will be 6.375; and this weight, as the ſame

chemist has shewn, accords very well with the constitution of the acetates.

ALLOY, in *Chemistry*, a combination of two or more metals. In addition to what has been said on this subject in the Cyclopædia, we may add the following tabular views from Dr. Thomson, of the general properties of the different alloys, as far as they have been examined. The chemistry of alloys is at present but little understood, and, as Dr. Thomson justly remarks, these compounds in general appear to be much better known to artists and manufacturers than to chemists.

The first of the following tables comprehends the alloys of the malleable metals with each other; the second, the alloys of the brittle metals; and the third, the alloys of the malleable and brittle metals. In these tables, the letter M signifies *malleable;* B, *brittle;* S, *submalleable*, used when the alloy is malleable in certain proportions, but brittle in others. O is used when the metals do not unite. The sign + is used when the alloy occupies a greater bulk than the separate metals; the sign — when the alloy occupies a smaller bulk. The first indicates an expansion; the second, a condensation.

TABLE I.—Malleable Metals.

	Zinc	Lead	Tin	Nickel	Iron	Copper	Iridium	Potassium	Sodium	Palladium	Mercury	Silver	Platinum
Lead	M												
Tin	M	M +											
Nickel	O	O	B										
Iron	S	B +	M	M									
Copper	S —	B +	B —	B	S								
Iridium						M							
Potassium	B	B	B		S								
Sodium	B	B	B										
Palladium		B	B +		B	S —		B					
Mercury	B	B	B	O	B	B		B	B	B			
Silver	B —	B —	B —	O	M	M +	M			M —	B —		
Platinum	B	S —	S —		M —	M —	M			M +	B	M +	
Gold	B —	B +	S —	M +	M +	M +	M			M	B	M +	M +

TABLE II.—Brittle Metals.

	Titanium	Tungsten	Chromium	Uranium	Molybdenum	Manganese	Cobalt	Arsenic	Tellurium	Antimony
Tungsten										
Chromium										
Uranium										
Molybdenum										
Manganese		B			B					
Cobalt					B					
Arsenic					B		B			
Tellurium										
Antimony			B		B	O		B		
Bismuth			B		S	O	O	B		B

Table III.—Malleable and Brittle Metals.

	Bifmuth.	Antimony.	Arfenic.	Cobalt.	Manganefe.	Molybdenum.
Gold - - - - - - -	B —	B —	B	B —	M	B
Platinum - - - - - -	B	B	B			B —
Silver - - - - - - -	B —	B —	B	B		B
Mercury - - - - - -	B	B	B	O	O	O
Palladium - - - - - -	B —		B			
Rhodium - - - - - -						
Potaffium - - - - - -	B	B	B			
Sodium - - - - - -	B	B	B			
Copper - - - - - -	B —	B —	M		M	S
Iron - - - - - -	B +	B +	B	B	S	B
Nickel - - - - - -	B		B +	B		S
Tin - - - - - - -	M	M ? +	B		B	
Lead - - - - - -	M —	M —	B	B		S
Zinc - - - - - -	O	B +	B	O	O	O

ANTIMONY, in *Chemiftry*. Several important additions have been lately made to our knowledge refpecting this metal and its compounds, which we fhall briefly notice here.

In defcribing this metal, we ftated that Haüy had been unable to afcertain its primitive cryftalline form. This indefatigable obferver has at length, however, determined that the primitive form of its cryftal is an octahedron, and that its integrant particles have the figure of tetrahedrons. The fpecific gravity of antimony, according to Hatchett, is 6.712. It melts at a low red heat, or about 810° of Fahrenheit; and after this, if the heat be raifed, the metal evaporates.

The oxyds of antimony have been lately inveftigated with great care by Thenard, Prouft, Bucholz, and Berzelius. According to Thenard, this metal forms no lefs than fix oxyds; according to Prouft and Bucholz, it forms only two; while according to Berzelius, it forms four. Thefe difcordancies arife from the great difficulty of the inveftigation. The protoxyd of Berzelius is obtained by expofing antimony to the air, or to the action of a galvanic battery. It is a grey powder. When acted upon by muriatic acid, it is feparated into the protoxyd of Prouft and metallic antimony. Hence Dr. Thomfon remarks it is only a mixture of the two. The two oxyds of Prouft are eafily obtained, and poffefs fpecific characters. Berzelius has fhewn that the fecond of them poffeffes the properties of an acid. The peroxyd of Berzelius is alfo readily obtained, though it is difficult to free it from water. This likewife poffeffes the properties of an acid. Hence, fays Dr. Thomfon, we know *three* oxyds of antimony. The *grey protoxyd*, the *white antimonious acid*, and the *ftraw-yellow antimonic acid*.

The following is the compofition of the *protoxyd* of antimony according to

	Prouft.	Berzelius.	Thomfon.
Antimony	100	100	100
Oxygen	22.7	18.6	17.775

Antimonious acid is compofed, according to the fame chemifts, of

Antimony	100	100	100
Oxygen	29.87	24.8	23.7

And *antimonic* acid of

Antimony	—	100	100
Oxygen	—	37.2	35.556

The above refults of Berzelius and Thomfon are rather obtained by calculation than actual experiment, being founded on the fuppofed compofition of fulphuret of antimony, which, according to Berzelius, is compofed of 100 antimony and 37 fulphur, and according to Thomfon, of 100 antimony and only 35.572 fulphur.

While fuch difcordancies exift refpecting the compofition of the oxyds of antimony, it is impoffible to fix with certainty the weight of its atom. Dr. Thomfon, however, it may be proper to ftate, confiders it as 56.25.

The two oxyds of antimony, denominated above the *antimonious* and *antimonic* acids, are capable, according to Berzelius, of combining with different bafes and forming two fets of falts, the firft of which may be termed *antimonites*, the fecond *antimoniates*.

The following is the method of preparing the *antimonium tartarizatum*, or tartrate of antimony and potafh, according to the laft edition of the London Pharmacopœia.

Take fulphuret of antimony pounded, two ounces; nitrate

of potash, one ounce; supertartrate of potash, two ounces; sulphuric acid *by weight*, two ounces; distilled water, a pint and a half. Mix the acid with half a pint of water in a proper glass vessel, and place it in a sand-bath. When moderately heated add by degrees the sulphuret and nitre previously well mixed together; and then apply heat till the whole of the water is driven off. Wash the remainder with distilled water until it comes off tasteless, and while the mass is yet moist mix it with the supertartrate of potash. To this mixture add a pint of distilled water. Boil the mixture, and when filtered put it aside to crystallize.

CANAL, col. 14, l. 44, add—The principal interior canals that are already (1818) completed in the United States are, the Middlesex canal, uniting the waters of the Merrimack river with the harbour of Boston, and the canal Carondelet, extending from Bayou St. John, a post of delivery in the Mississippi district, to the fortifications or ditch of New Orleans, and opening internal communication with lake Pontchartrain. The union of this canal by lakes with the Mississippi would, independently of other advantages, enable the government to transport with facility and effect the same naval force for the defence both of Mississippi and lake Pontchartrain, the two great avenues by which New Orleans may be approached from the sea. In 1816 or 1817, the state legislature of New York passed acts, appropriating funds for opening a navigable communication between the lakes Erie and Champlain and the Atlantic ocean, by means of canals, connected with the Hudson river. When this scheme, actually begun, is accomplished, and a communication opened by canals and lakes between lake Erie and the navigable waters of Hudson's river, and also between lake Champlain and these waters, the state of New York will soon become, in itself, a powerful empire.

Sheet Q q, instead of CANAL at the head of the page, insert in col. 1 and 2, CAN.

CANAL, p. 44, col. 2, l. 6 from the bottom, for thereon *r.* therein. P. 49, col. 1, l. 20, add—Mr. Chapman has lately (*viz.* in 1816) suggested to the editor, that this method, without complicated collateral aid, not had in contemplation, will be found to be impracticable; because the moment the descending crisson entered the lower canal, the equilibrium would be lost, and all counterbalance when the crisson had entered to such depth as to allow its contained vessel to go out.

For HARTLEPOOL CANAL *r.* HARTLEY CANAL; for Durham *r.* Northumberland; and for Hartlepool *r.* Hartley.

CANAL, *Basingstoke*, col. 2, l. 3, after commences in, insert—Cooper's meadow, adjoining to the town of Basingstoke, and enters the river Wey about two miles above Weybridge; *dele*, l. 3, 4, 5, from Wey to Basingstoke; l. 18, after Lodden, add—The proprietors are prohibited from touching the Lodden, or any of the springs or streams that feed it.

CARBON, in *Chemistry*. The progress of chemical knowledge enables us to state, with greater accuracy and precision, the nature of some of the compounds of carbon, than at the period when this article in the Cyclopædia was written.

Carbonic Oxyd.—It has been shewn by Gay Lussac, that 100 measures of this gas require for complete combustion 50 measures of oxygen, and that the product is 100 measures of carbonic acid; hence it must be composed of one atom of carbon and one atom of oxygen, or 100 parts by weight will consist of

Oxygen	57.14
Carbon	42.86
	100.00

And its true specific gravity must be .9722, and 100 cubic inches of it must weigh, at a mean temperature and pressure, 29.652 grains. Carbonic oxyd has the property of combining with chlorine, and forming a peculiar compound, which its discoverer, Dr. Davy, has named PHOSGENE *gas*; which see.

Carbonic Acid.—When pure charcoal is burnt in oxygen gas, it has been shewn that the original bulk of the oxygen suffers no change. Hence it is obvious, that, by subtracting the specific gravity of oxygen from that of carbonic acid gas, we shall obtain the quantity of carbon existing in it. The specific gravity of oxygen gas is 1.11, and that of carbonic acid 1.52. Hence 100 parts, by weight, of carbonic acid will consist of

Oxygen	72.73
Carbon	27.27
	100.00

which correspond with two atoms of oxygen and one of carbon. See ATOMIC *Theory*.

Carburetted Hydrogen.—The specific gravity of carburetted hydrogen, according to Dr. Thomson, is .5555, and 100 cubic inches of it weigh 16.99 grains. It requires for its complete combustion twice its volume of oxygen gas, and produces exactly its own volume of carbonic acid; the only remaining product is water. Hence 100 parts, by weight, of this gas are composed of

Carbon	75
Hydrogen	25
	100

which correspond with one atom of carbon and two of hydrogen.

Olefiant Gas.—The specific gravity of this gas, according to Dr. Thomson's experiments, is .974, and 100 cubic inches of it weigh 29.72 grs. It requires for its complete combustion three times its volume of oxygen gas, and produces, when burnt, twice its volume of carbonic acid gas, and a certain proportion of water. Hence 100 parts, by weight, of this gas are composed of

Carbon	85.71
Hydrogen	14.29
	100.00

which correspond with one atom of carbon and one of hydrogen.

The curious oil-like compound formed by the union of this gas with chlorine, has been lately examined by MM. Robiquet and Colin. They found that it is composed of one volume of chlorine united with one volume of olefiant gas, and of course that its constituents, by weight, are

Olefiant gas	- -	16.28
Chlorine	- - -	83.72
		100.00

This oily liquid, which Dr. Thomfon confiders as a fort of *ether*, and hence names it *chloric ether*, burns with a green flame, and at the fame time gives out copious fumes of muriatic acid and much foot. Its fpecific gravity at 45° is 1.2201, water being 1.000. It boils at 152°. At the temperature of 49°, its vapour is capable of fupporting a column of mercury 24.66 inches in height. The fpecific gravity of this vapour was found by experiment to be 3.4434, which very nearly coincides with the above account of its compofition. When paffed through a red-hot porcelain tube it is decompofed and converted into muriatic acid, and an inflammable gas containing hydrogen and carbon, while a copious depofit of charcoal is found in the tube. It is alfo decompofed when paffed through red-hot oxyd of copper.

With refpect to the *carbonates*, the numbers reprefenting them will of courfe require a little adjuftment; this can be eafily done from the compofition of carbonic acid ftated above, and from the data given under ATOMIC *Theory*.

CARBONIC *Acid Gas*, col. 2, l. 5, add—According to the accurate experiments of Meffrs. Allen and Pepys, recorded in the Phil. Tranf. the weight of a cubic inch of this gas is .464 of a grain. Col. 3, l. 46, *r.* milkinefs.